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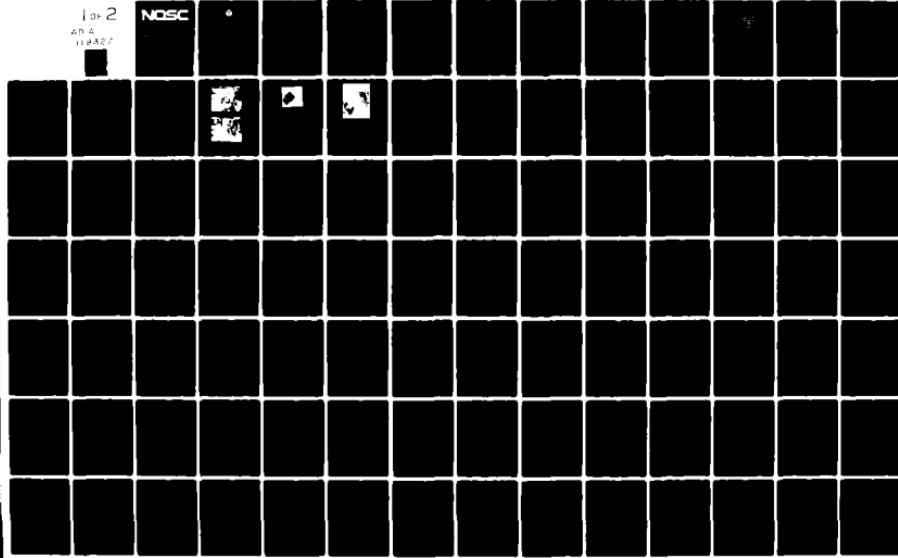
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WORK SYSTEMS PACKAGE AUTOMATIC TOOL INTERCHANGE

Laboratory study shows that automating
certain WSP functions is feasible

CE Morrin

10 June 1982

Final Report for Period October 1977 – June 1978

Prepared for
Naval Sea Systems Command
Washington DC 20362

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ADMINISTRATIVE INFORMATION

This study was made for the Naval Sea Systems Command by members of the Advanced Systems Division (Code 521), under Program Element 63713N, Project SSL49001, Task Area 16617, as part of an effort to develop automation of certain functions of the Work Systems Package. This report covers work performed during FY78 and was approved for publication 10 June 1982.

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METRIC CONVERSION

<u>To convert from</u>	<u>to</u>	<u>Multiply by</u>
feet	metres (m)	$\sim 3.05 \times 10^{-1}$
inches	m	$\sim 2.54 \times 10^{-2}$
pounds	kilograms (kg)	$\sim 4.54 \times 10^{-1}$
minutes (angular)	radians (rad)	$\sim 2.91 \times 10^{-4}$
pounds per square inch (psi)	kilopascals (kPa)	~ 6.89
tons (short)		
gallons per minute (gpm)	megagrams (Mg)	$\sim 9.07 \times 10^{-1}$
	m^3/s	$\sim 6.31 \times 10^{-5}$

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The Work Systems Package (WSP) is a remotely controlled manipulator with tools and support equipment, developed to interface with manned and unmanned underwater vehicles to perform ocean-floor salvage, recovery, installation, and repair tasks. Since bottom time is limited, risk factors are high, and visibility often is poor or hampered, automation of certain WSP functions would take advantage of the limited available power and reduce the risk factor. Automating the WSP via a computer program allows the WSP accessories (eg, tool box and tools) to be moved out of the prime visibility area of a manned vehicle and helps the operator to perform tasks faster and more efficiently.		

OBJECTIVES

1. Determine the feasibility of automating the tool interchange portion of the tasks performed by the Work Systems Package (WSP) by conducting a laboratory demonstration.
2. In particular, demonstrate that automatic tool interchange can be performed repeatedly without malfunction when the WSP is equipped with fixed-rate position control (hydraulic solenoid valves).

RESULTS

1. The feasibility of automatic tool interchange with the WSP was demonstrated in the laboratory.
2. Equipped with fixed-rate position control, the WSP performed automatic tool interchange repeatedly without malfunction.

RECOMMENDATIONS

1. Incorporate automation into the next work system that is built.
2. Ultimately, conduct in-water tests of the automated work system to verify its feasibility.



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INTRODUCTION

BACKGROUND - THE WORK SYSTEMS PACKAGE

The Work Systems Package (WSP) program, part of the Deep Ocean Technology (DOT) project, was initiated in February 1972 by NOSC in conjunction with the Battelle Memorial Institute (Columbus OH), the Naval Civil Engineering Laboratory (Port Hueneme CA), and the David Taylor Naval Ship Research and Development Center/Annapolis (Annapolis MD), under the direction of the Naval Sea Systems Command.

The WSP is a 5-ton, neutrally buoyant machine assembly designed for ocean-floor salvage, recovery, installation, and repair operations at depths to 20 000 feet. It has restraining and manipulator arms and hands, specially designed tools and a customized tool box, a video monitoring system, required support equipment, and a self-contained power source. It is intended to provide a heavy-duty underwater work capability for the Navy's Cable-Controlled Underwater Recovery Vehicle, CURV III, or Remote Unmanned Work System (RUWS), both cable-controlled submersible vehicles, and the manned vehicles Alvin, Sea Cliff, and Turtle (ref 1). It can also be positioned and controlled without a submersible, from a surface support ship or by divers.

The WSP performs its work functions without having to resurface for tool interchange. The two outer restraining (grabber) arms attach to the work piece to maintain a stable physical orientation with the work object. The manipulator, located between the grabbers, is a seven-function articulated arm that can select, interchange, and operate a variety of hydraulically powered, explosively actuated tools. With the tools it can cut cable or synthetic line, torque nuts, jack, pry, wire-brush, saw, grind, drill, tap, chip, and

1. Design for Remote Work in the Deep Ocean, by RL Wernli (NOSC), paper published in ASME publication 78-WA/OCE-4, contributed by the Ocean Engineering Division of the American Society of Mechanical Engineers for presentation at the ASME Winter Annual Meeting, San Francisco CA, 10-15 December 1978.

drive studs. The integral tool box has "pigeonholes" and brush-type retainers for the various tools and external clip mounts for the tool bits. The primary power source is a 60 V dc lead-acid battery bank, which drives a 1-gpm 2000-psi motor-pump unit for operating the manipulator and a second, high-flow, 2.5-gpm 3000-psi motor-pump unit for powering the tools. High-pressure oil for tool actuation is supplied through two external hydraulic hoses to quick disconnects at the manipulator hand. The operator controls the WSP functions from the host vehicle, through a multiplexed telemetry circuit.

SCOPE OF THIS REPORT

The basic WSP components used in the automatic tool interchange study reported here were developed in the course of the WSP program and have been employed continuously since its inception in 1972 (ref 2, 3). This report focuses on (1) the modifications and added components (ref 4) necessary to effect automation of the WSP and (2) the analyses and tests used to demonstrate the feasibility and accuracy of the automated device.

DESIGN OF THE WSP TOOL INTERCHANGE

Work systems previous to the WSP had been employed, but only one or two tools were used on a single dive. The main objective of the original WSP was to provide a large number of tools and a tool interchange capability. This was intended to allow the operator to perform very complex missions in only one dive.

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2. Development of a Design Baseline for Remotely Controlled Underwater Work Systems, by RL Wernli (NOSC); paper published in IEEE publication 78 CH 0134-7 OEC, Oceans '78, record of the Fourth Annual Combined Conference sponsored by the Marine Technological Society and the IEEE Council on Ocean Engineering, held in Washington DC, 6-8 September 1978, p 130.
 3. NOSC TR 214, Evaluation of the Design and Undersea Work Capability of the Work Systems Package, by WR Bertsche, KP Logan, AN Pesch, and RL Wernli (Principal investigator), 1 April 1978.
 4. NOSC TN 360, NOSC Informal Progress Report, Fiscal Year 1977; Work Systems Package (WSP) Program, by RL Wernli, 1 April 1978. NOSC TNs are informal documents intended chiefly for internal use.

The designers were concerned that the operator would find tool interchange difficult. Consequently a premise of the early design process was that tool interchange had to be conducted in the best viewing area - with some diminution of the mission operating area if necessary. Thus the large, unwieldy tool box of the WSP was located in the prime operating area. Subsequent testing and analysis demonstrated that tool interchange could be accomplished easily by means of this approach.

AUTOMATION OF THE WSP

In this study, automation of the tool interchange was considered. This approach would permit the tool box to be located outside the prime operating (viewing) area. There were two concerns:

1. There were no known automated robotic systems that worked in the deep ocean.
2. The known high precision robotics (NASA and assembly line automation) all used variable-rate control rather than fixed-rate (solenoid) control.

The WSP manipulator is factory equipped with solenoid valves (for fixed-rate control). Besides being less expensive, fixed-rate control consumes less power - an important consideration since the WSP operates on batteries and its power consumption limits its mission time.

Deep-diving manned submersibles are limited in both the power available to perform work operations and the amount of life-support power available to the crew. A reduction in overall operating time may allow a mission to be completed more quickly or may allow more work to be done per dive. For a 20 000-foot dive, the effect can have a significant impact on the overall operation of the mission. For a tethered submersible, which may have unlimited power available, time reductions would be the primary factor. During operations under adverse weather conditions, the weather window available for operation of tethered systems may be very small. Thus the importance of expedience in such missions, as was shown dramatically during the recovery of

an F-14 off Scotland.* In any case, reduction of operator fatigue - especially in a manned boat, where comfort is not the general rule - would be advantageous.

Although automatic tool interchange was considered too risky for immediate implementation in an operational WSP, a task was begun to evaluate the feasibility of automation. A programmer to effect automatic manipulator control through fixed-rate control valves was built and demonstrated on the linkage manipulator (ref 4). Since the results of this preliminary test were encouraging, it was decided to go ahead with evaluating the feasibility of automatic tool interchange on the WSP. This paper describes that effort.

SYSTEM DESCRIPTION

FUNCTIONAL DESCRIPTION

Further tool interchange technology that had to be developed before the objective could be achieved included (1) modifying the WSP manipulator by adding angular position sensors to the manipulator joints that were to be automatically controlled, (2) providing the necessary command and feedback interfaces between a microprocessor and the WSP manipulator, and (3) devising a tool-interchange computer program for the microprocessor. Tests then could be conducted to demonstrate whether automatic tool interchange could be performed repeatedly without malfunction.

*An F-14, equipped with a Top Secret Phoenix missile, fell into 2000 feet of water from a carrier off the coast of Scotland in September 1976. Soviet trawlers observed the incident.

Recovery of the F-14 was ordered by President Ford, but the search and recovery operations took more than a month because of adverse weather conditions, typically sea state 4-5.

When the F-14 was recovered, there were two fishing nets wrapped around it. Although it was too big for the nets, the Phoenix missile easily could have been recovered accidentally by fishermen.

Figure 1 is a functional block diagram of the WSP demonstration system.

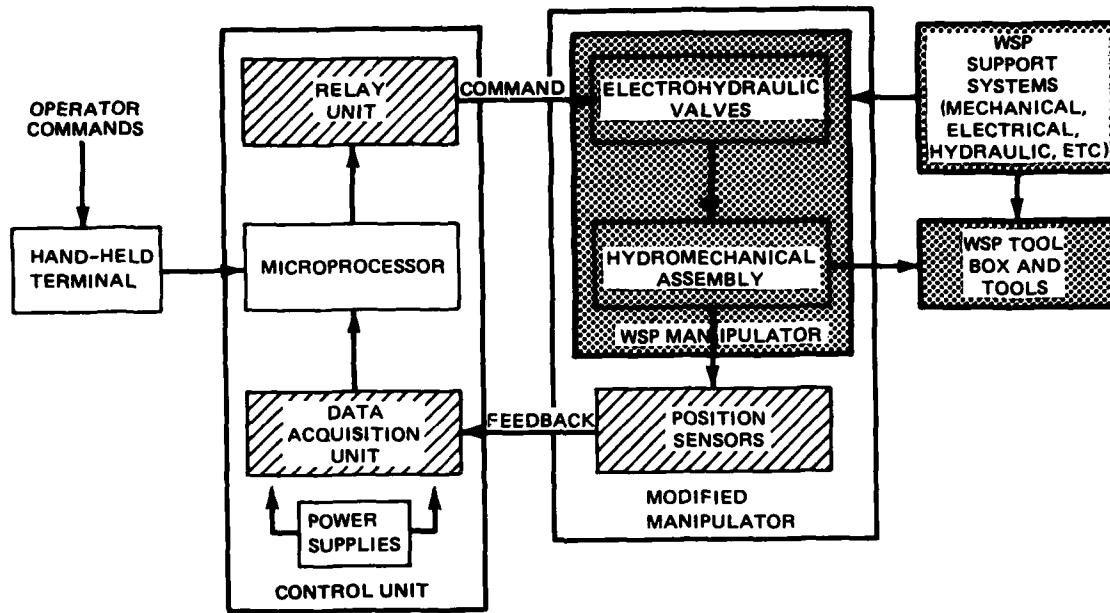


Figure 1. Automatic tool interchange demonstration system functional block diagram. The shaded areas represent existing WSP components used in the study, the cross-hatched areas represent developmental components, and the clear areas represent existing non-WSP components.

SYSTEM REQUIREMENTS

Accuracy

The basic accuracy requirement is that the manipulator be able to hit within the alignment guides on the tool. Table 1 shows the specifications derived for the WSP manipulator. It is assumed that the guides are designed for a maximum error of 0.25 inch and that the manipulator contains a tool that extends 1 foot beyond the tip of the hand.

Option	Manipulator Joint*	Position Error, inches		Angular Error, minutes	
		Nominal	Desirable	Nominal	Desirable
1—Same error for each function (standard deviation)	SL	0.045	0.020	2.0	1.0
	SU	0.045	0.020	2.0	1.0
	E	0.045	0.020	3.0	1.5
	WU	0.045	0.020	4.0	2.0
	WL	0.045	0.020	4.0	2.0
	Overall	0.100	0.040		
2—Same encoder for all functions	SL	0.055	0.020	2.5	1.0
	SU	0.055	0.020	2.5	1.0
	E	0.040	0.015	2.5	1.0
	WU	0.025	0.010	2.5	1.0
	WL	0.025	0.010	2.5	1.0
	Overall	0.100	0.040		

*SL = shoulder left/right

SU = shoulder up/down

E = elbow up/down

WU = wrist up/down

WL = wrist left/right

Table 1. Allowable position error of each manipulator arm functional element and derived allowable angular error of each associated joint.

Table 2 shows the angular ranges over which the joints with sensors can be controlled and the much narrower ranges over which a tool can be controlled accurately.

Manipulator Joint	Control Range, °	High-Accuracy Range, °*
SU	210	45
SL	180	120
E	270	**45
WU	270	**45
WL	180	5

* Subject to change, depending on tool box design and work area limits.

**These functions could be less inhibited if the elbow and wrist up/down potentiometers were not coupled to the shoulder up/down movement.

Table 2. Ranges of control and high accuracy.

Temperature Variation

Accuracy must be maintained over a temperature variation of 0° to 30°C.

Drift

Accuracy must be maintained for at least 1-2 months. If accuracy can be maintained for 1-2 years, maintenance requirements would be substantially lower. If this system is to be delivered to Navy operating forces, the 1-2 year requirement is probably necessary.

Long-Term Drift

Accuracy must be maintained over a period of 1 year. Therefore, electronics drift must be controlled.

Shock and Vibration

The system must be designed to withstand a standard shipboard environment.

Linearity

Linearity is not required but is desirable in that it would allow more sophisticated software techniques.

MANIPULATOR

The manipulator (ref 1, 3), manufactured by Programmed and Remote (PaR) Systems Corporation, is actuated by individual hydraulic motors or actuators that articulate shoulder rotate and pivot, elbow pivot, wrist rotate and pivot, and hand open and close motions. Hydraulic supply pressure to each function is gated on or off by electrical commands to associated built-in electrohydraulic solenoid valves.

POSITION ENCODING

The angle between the elements comprising each joint of the manipulator (except wrist rotate and hand open/close) must be accurately measured and converted to a voltage, to provide the feedback necessary for computer-controlled automation of the tool interchange function.

POSITION FEEDBACK TRANSDUCERS

Angular position can be sensed satisfactorily by either an absolute or an incremental encoder. The incremental encoder is easier to align when realignment is necessary, but it has to be reinitialized after power loss.

At least four types of transducers exist for this purpose:

Electromechanical (potentiometers)

Optical

Magnetic (synchros)

Mechanical (pin contacts)

Potentiometers, which are functionally absolute, may be wire-wound, ceramic-metallic (cermet), made of conductive plastic, etc. Conductive plastic potentiometers were selected for sensors in this study because they are inexpensive and easily interfaced. These potentiometers, used successfully in the demonstration, had accuracies of 1 part in 10 000. It is questionable, however, whether long-time accuracy better than 1 part in 2000 to 4000 can be achieved under shock, vibration, and variations of temperature and power-supply voltage. This degree of accuracy should be acceptable if two or more potentiometers can be stacked on the same shaft—one for coarse measurement, one for fine.

Optical encoders can be either absolute or incremental. Off-the-shelf incremental optical encoders are available with accuracies of 1 part in 20 000, but their ability to withstand pressure has not been established.

Synchros are probably the best type of position sensors. They are relatively expensive, however, and the high-accuracy versions tend to be significantly larger than potentiometers.

Pin-contact sensors do not have sufficient accuracy.

MODIFICATION DESCRIPTION

To provide angular-position feedback signals necessary for automatic operation, manipulator precision potentiometers were attached to the five applicable joints (fig 2). The devices chosen were Bourns Instrument Company 7/8-inch diameter, servomount, 10 k Ω conductive plastic potentiometers, type

6534S-1-103. They were externally mounted on the shoulder azimuth, shoulder pitch, elbow pitch, wrist pitch, and wrist azimuth functions (fig 3) by means of lightweight, inexpensive potentiometer mounts. For simplicity of operation, wrist rotation and hand open/close were operated by direct switch control, without feedback.

CONTROL UNIT

The control unit (showing in the background, fig 3) consists of a microprocessor, a relay unit, a data acquisition unit, and associated power supplies. The microprocessor is programmed as follows:

1. To respond to discrete control signals from the hand-held terminal function buttons by causing the relay unit to send various combinations of electrical commands to the electrohydraulic valve solenoids, driving the manipulator in selected motions.
2. To stop the manipulator motions at predetermined positions of the manipulator hand as determined by processing feedback voltages received via the data acquisition unit from the manipulator joint angular sensors.

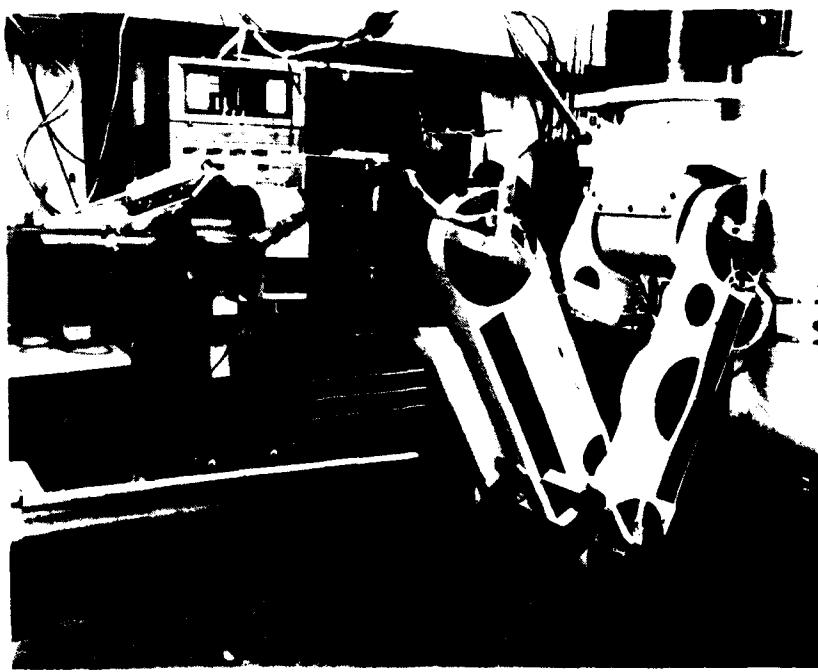
TERMINAL

The hand-held terminal, manufactured by Termiflex (fig 4), was adapted for operator programming and command input to the control unit and for limited CRT display of monitored functions. It is ideal for use in the confined environment of a manned submersible. The operator inserts codified instructions into the microprocessor by punching appropriate pushbuttons on the terminal's miniature keyboard.



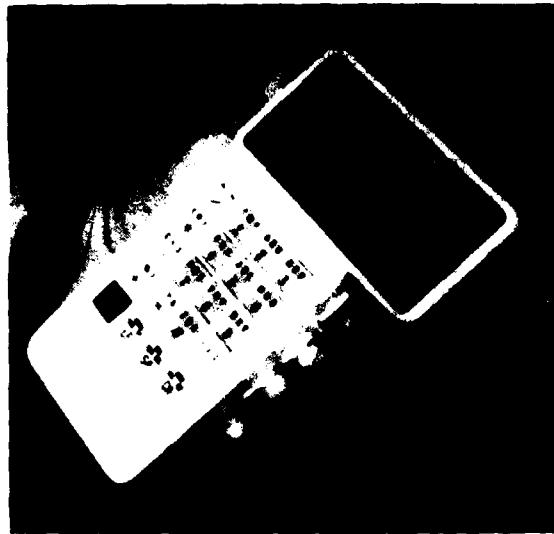
LRO 466-2-78B

Figure 2. Closeup of one of five potentiometer mounts on WSP manipulator.



LRO 466-2-78B

Figure 3. Overall view of WSP manipulator with position encoding potentiometers mounted appropriately at joints.



LRO 467-2-788

Figure 4. Termiflex HT/2 hand-held computer terminal.

TOOL BOX AND TOOLS

The tool box (fig 5) and tools used in the study were those developed for the WSP (ref 1).

PROGRAMMER

DESIGN REQUIREMENTS

Precision control of a solenoid-controlled manipulator is a significantly different process from precision control of a servo-controlled manipulator. A servo unit can be slowed down as it approaches the desired point. A solenoid unit, however, is turned off abruptly somewhat before reaching the desired point; its final position depends on how far it moves during valve closure.



LRO 4851-8-77

Figure 5. Tool box.

The algorithm for the control unit is as follows:

1. Determine which direction to move manipulator.
2. Open solenoid; manipulator starts moving.
3. Monitor position of manipulator.
4. When manipulator reaches critical position, turn off (close) solenoids.
5. Effect no further control until manipulator stops moving. (There may be several oscillations.)
6. Compare final position of manipulator to desired position. If error is significant, try again.

Several quantitative data values are associated with each movement, as follows.

Desired Location

The desired location (preprogrammed) is selected by the operator. The coordinates of the desired location are initially determined by moving the arm to that location and automatically reading the coordinates (potentiometer readings). Known coordinates can be entered by the operator.

Tolerable Error

The maximum error is based on the following model. The manipulator is moved towards the tool box by using five functions in a sequence. The final operation - extend - consists of two simultaneous functions. On this final extend operation, the manipulator must contact the alignment grooves on the tool box. When the manipulator hand reaches the tool box, the maximum correctable error is 1/4 inch in any direction, within a plane perpendicular to the extend function travel. (This is discussed further in appendix C.)

Solenoid Turn-off Point

The "coasting time" is a function of the following:

Individual manipulator function.

Direction of travel. The length of coast is greater for down movement than for up movements.

Weight of manipulator. Usually this factor is limited to the weight of the object being transported.

Hydraulic pressure. The hydraulic pressure drops when more than one function is operated. Consequently it is difficult to estimate the coasting time if another function is operated and the one which will turn off first is not known.

Water depth. Ambient pressure increases with depth. This may affect the coasting time, but there are no data available.

Required Feedback Sampling Rate

The sampling rate is determined primarily by the rate at which the arm moves. The worst-case sample rate occurs with shoulder movements since they move the fastest. Shoulder movements cause the hand to move through an arc of about 7-foot radius. At 1.26 rpm, the tip speed is thus 11 inches per second. The shoulder has a nominal accuracy of 0.05 inch (see appendix C). The manipulator travels 0.05 inch in about 4.5 ms. Consequently, the decision time should be less than 450 μ s. A 45- μ s decision time was established as a design goal to eliminate this parameter as a problem. The final design required 30 μ s between decisions (33 kHz sample rate).

FUNCTIONAL DESCRIPTION

The control unit contains the following components:

- Data acquisition unit
- Microprocessor
- Hand-held terminal
- Relays

Data Acquisition Unit

Potentiometers are attached to the manipulator. A precision voltage source (20 ± 0.001 V) provides power to the potentiometers via a shielded twisted pair. Other shielded twisted pairs bring the wiper voltage and the negative reference to the analog multiplexer.

The analog multiplexer has two stages. The first stage selects two potentiometer signals and inputs them into high-accuracy, slow-settling, differential instrumentation amplifiers. The second stage is used for the rapid selection of one of the two signals selected by the first stage. This signal is measured by a high-speed 14-bit analog-to-digital converter. The A/D converter and multiplexer operate under computer control.

Microprocessor

An Intel 8080 microcomputer monitors the potentiometers and controls the relays as commanded by the operator. The computer contains random access memory so that the operator can program manipulator sequences, then perform them. Also provided is erasable programmable read-only memory (EPROM), for long-term storage of preprogrammed manipulator sequences.

Hand-Held Terminal

The Work System Package was designed to be attached to the Alvin submersible. To meet this requirement, the manipulator was controlled from a small hand-held box. For the purpose of this study, a small hand-held computer terminal (Termiflex HT-2) was selected to perform the operator-machine interface. The primary limitation on such a device is the display rather than the controls. The terminal displays two lines of ten alphanumeric characters each. It also has a scroll capability with access to 100 lines. The interface was designed so that the operator receives immediate feedback from only the last two lines of data. Consequently the operator normally does

not have to use the scroll feature, although it is available for reviewing previous operations.

Relays

Telephone-type relays are used to select two solenoids. Two solid-state relays are then used to turn the solenoids on and off in a predictable time period. (Note: tests on the linkage manipulator used reed relays because of different electrical requirements.)

TEST DESCRIPTION

FUNCTIONAL TESTS

First, three elementary tests were made on the automated system. The first of these was to acquire a tool and a bit and then to move to the work area, where control was returned to the operator. The second was to return the tool and bit to the tool box. The third was to drill a hole automatically.

Next, these three separate sequences were linked together. Without any intervention by the operator, the programmer was able to direct the manipulator to obtain the drill and bit, drill a hole, and return the tools to the tool box.

A fallback objective was also considered: to evaluate the mating (and/or disconnect) of the tool and manipulator, which is the most critical operation. In still another test, the microcomputer was programmed to position the manipulator directly in front of the tool such that the operator could easily acquire the tool.

In actual practice in the deep ocean, the automatic operation should stop at these critical points and allow the operator to look at the manipulator through the TV. When the manipulator has acquired a tool, the operator must make a visual check to see that the tool is securely locked onto the manipulator before the tool is brought out. Similarly the operator must make sure that the tool is released after it is replaced so that the manipulator does not drag it back out, causing it to fall to the ocean floor. Note that the operator needs only one TV camera for these critical checks, since he is not actually controlling the manipulator.

There was no attempt to run the automatic controller fast. In fact, it was slowed down at every opportunity in the effort to obtain consistently reliable results. Sequential operation was programmed, wherever feasible. Intermediate stopping points were programmed in. After each move, the controller waited for the arm to come to a complete rest. (This precaution was not always necessary.)

Despite these limitations, however, the system performed faster under programmed operation than under manual. Time reductions in operation are important since they lower the energy storage requirements of battery-operated submersibles or other platforms on which such a system would be used. Micro-computer control allowed the manipulator to repeat motions with such accuracy that tool and bit exchanges were successfully completed under exclusive control of the programmer.

Note that the configuration of the WSP was optimized for manual operation; if a less exposed position were chosen for tool-box placement, as could be done with automatic tool exchange, further improvement in operation could be expected. Although the functional test established that complete tool interchange could be programmed and accomplished without human intervention, simple movement to a point in space was complicated by tool-box compliance (as well as a manipulator malfunction). Programming the tool interchange process was far more difficult than anticipated. The problems experienced are each discussed briefly as follows, along with their solutions.

The WSP was designed to acquire tools with a final movement in which the manipulator hand extends linearly in the proper direction. But in the linear extend function, the manipulator arm was found to experience a significant droop. The linear extend function requires simultaneous actuation of the shoulder up and elbow down functions. The up function requires the greater amount of power, to overcome gravity, but the power input is the same for each function since all solenoid valves and hydraulic actuators of the manipulator are identical. The solution to this problem was to program a series of intermediate points at each of which the position of the hand would be corrected.

Attempts to extend directly toward the center of the tool were successful only part of the time; the manipulator hand frequently would hit an adjacent tool bin. The operator could avoid this problem by manually controlling the nonautomated hand open/close and wrist rotate. (The computer does not have a feedback sensor on those functions.) This obstacle was removed by programming the manipulator to move to a point about 1 inch from the tool and 0.25 inch off center, then to realign both the shoulder and wrist left-right functions to the center of the tool.

Grasping the tool required that significant pressure be exerted on it. This could not be programmed simultaneously with position control, since the tool box would move substantially before the pressure became sufficient to overcome binding between the tool and the tool box, and any movement accompanied by binding would cause significant change in the position of the tool box. It was found that grasping the tool could be accomplished sequentially, by careful alignment at the final intermediate position followed by a 5-second linear extend.

The tool acquisition phase ends with the tool box pushed several inches from its normal position and the tool locked in the box by binding forces. Tool removal from the box is difficult because of the binding tendencies of the very compliant tool box. "Nonlinear" retraction also causes binding. It was found that removal of the tool could be accomplished by realigning the manipulator every 2 inches or so.

The movement for tool insertion into the tool box after use is entirely different from the tool acquisition movement. It was solved primarily by programming in a large number of intermediate "stopping for realignment" points.

Removal of the hand after tool insertion into the tool box is difficult, since the hand tends to pull the tool back out. Inadvertent pullout of the tool was minimized by programming in several sequential small movements alternating with realignments.

Tool seating, the final step in tool stowage, is achieved by a separate sequence of closing the manipulator hand, then pushing the tool with the tip of the hand for several seconds.

A problem that occurred throughout the tests is that moving one function would cause the potentiometer of another function to change. Specifically, moving the shoulder up or down caused three potentiometers to change (shoulder up/down, elbow up/down, and wrist up/down). Also, the elbow up/down function caused movement of the wrist up/down potentiometer. If the potentiometers had 0.001% linearity, these changes could have been compensated for. Since they were only about 0.01% linear, however, it was necessary to move the shoulder up/down to a known position before the elbow up/down could be aligned precisely. Alignment of the wrist up/down was more complex, since before it could be aligned, both the shoulder up/down and the elbow up/down had to be moved to known locations. This problem could be cured by attaching the potentiometers such that they would be moved independently.

ACCURACY TESTS

Several types of accuracy tests were performed next for the purpose of determining the expected consistency of performance, helping identify problem areas, and discovering the cause and magnitude of errors so that means could be devised to correct them. The objectives of the tests were as follows:

1. Estimate the overall accuracy of the programmer.
2. Estimate the mean and variance of the coasting distance* for the shoulder, elbow, and wrist function movements.
3. Estimate the error contribution due to each of those functions.

At the conclusion of these tests, potentiometer noise was measured to determine its effect upon accuracy.

The tests were performed in the following sequence. The programmer was directed to move the manipulator through a series of tool exchanges and, between each exchange, to return it to a predesignated location about 6 feet from the manipulator shoulder pivot point, aligned with a specific spot on a target. After completion of the movement, the alignment error at the target was measured with a ruler and protractor. In addition, the predicted errors were read out of the control unit and recorded.

Two sets of ten identical movements were performed. The standard deviation was determined, and further analysis was done to determine the cause of error.

The manipulator movements were determined by the solenoid turn-off points. These were determined with sufficient accuracy to verify that the system passed the tests, but the programmer was not adjusted to yield optimal results. The errors were averaged to determine the true point to which the manipulator was programmed to move, and all further analyses used this point as a reference.

*The distance traveled after the command is issued to turn off the solenoid valve.

TEST RESULTS

STANDARD DEVIATION

At the end of each movement (tool exchange), the error relative to the desired point was measured. These data contain a systematic error in that the programming was not optimal. The error was then calculated relative to the mean of the final positions. (Position was described by means of clock notation.)

The error relative to the reference point was less than 1/4 inch in all cases (table 3). The standard deviation of the error was 0.108 inch. This indicates a 98% probability of meeting the requirements on each movement; ie, alignments would have to be repeated less than 2% of the time.

Run	Total Error		Error Relative to Mean	
	Magnitude, fraction of inch	Position, o'clock	Magnitude, fraction of inch	Position, o'clock
1	1/8	9	0.06	8
2	1/8	9	0.06	8
3	1/8	9	0.06	8
4	1/8	9	0.06	8
5	1/8	9	0.06	8
6	1/32	9	0.07	4
7	1/8	9	0.06	8
8	1/8	9	0.06	8
9	1/8	10	0.03	8
10	3/16	7	0.21	6
11	1/8	12	0.12	2
12	1/8	12	0.12	2
13	1/8	12	0.12	2
14	1/8	12	0.12	2
15	0	-	0.10	4
16	1/16	9	0.05	5
17	3/16	10	0.09	10
18	1/8	8	0.11	6
19	1/4	11	0.18	12
20	1/4	11	0.18	12

Mean of the final positions: = -0.085 inch, = +0.043 inch

Standard deviation = 0.108 inch

Standard deviation (left/right only) = 0.057 inch

Standard deviation (up/down only) = 0.092 inch

Table 3. Programmer accuracy test results.

CONTROL UNIT ERROR READINGS

Control unit error readings were taken for each potentiometer at the end of each test movement. Error was measured in parts per 16 000 relative to the preprogrammed reference point. The control unit readings (table 4) were used to estimate coasting distances and accuracies for each of the individual functions. The results were as follows.

Test No	Manipulator Accuracy, potentiometer readings.				
	Shoulder Up/Down	Elbow Up/Down	Wrist Up/Down	Shoulder Right/Left	Wrist Right/Left
1	-4	-4	4	4	4
2	-1	-1	4	5	-5
3	-3	-1	4	2	-3
4	+1	-2	6	4	0
5	-3	-2	6	2	-2
6	0	-1	6	2	-1
7	-4	-1	5	1	-2
8	-1	0	5	0	-3
9	-1	-1	5	0	1
10	-2	0	5	2	3
11	+1	-6	4	2	10
12	-3	0	7	1	4
13	-1	0	8	-5	5
14	-3	0	8	0	10
15	-4	-3	-10*	0	8
16	-2	-2	-11*	0	7
17	-5	-1	8	1	4
18	-4	-2	-6	-1	5
19	-4	-1	8	0	8
20	-3	0	7	-3	5
Mean	-2.55	-1.4	+3.6	+0.85	+3.10
Standard deviation	1.6	1.5	5.6	2.3	4.6

*Solenoid actuated (see text)

Table 4. Control unit error reading. To convert control unit error into absolute error: 1 part in 16 000 over 270° represents 1 minute of arc, or 0.017°.

Shoulder Up/Down

The shoulder up/down function had a dead-band width of 24 units (0.63 inch). The arm coasted 9.5 units (0.24 inch) with a standard deviation of 1.6 units (0.040 inch).

Elbow Up/Down

The elbow up/down function had a dead-band width of 40 units (0.71 inch). The arm coasted 18.6 units (0.33 inch) with a standard deviation of 1.5 units (0.027 inch).

Wrist Up/Down

The wrist up/down function had a dead-band width of 24 units (1.14 inches). The coasting distance could not be accurately estimated since there were two wrist alignments during the final movement and only the first movement was actuated during 17 of 20 tries. (Note: the first ten movements had three wrist up/down movements; the last ten had four wrist up/down movements.)

The wrist up/down function was inconsistent during the final ten runs because of a programming error. Dead-band was set at ± 5 units. The previous position was very close, about -3.5 units, with the result that the solenoids were not activated about 50% of the time. When the previous position was -5 or lower, the solenoids would be activated and the wrist up/down moved to +2 units; ie, the wrist up/down went to one of two positions that were 0.25 inch apart.

Shoulder Left/Right

The shoulder left/right function had a dead-band of 40 units (1.00 inch). The arm coasted 17.5 units (0.438 inch) with a standard deviation of 2.3 units (0.058 inch).

Wrist Left/Right

The wrist left/right function had a dead-band of 40 units (0.40 inch). The arm coasted 23.5 units (0.23 inch) with a standard deviation of 4.6 units (0.046 inch). Further analysis indicated that there was a significant difference between the first ten movements and the second ten. The first ten coasted an average of 19.2 units (0.19 inch) with a standard deviation of 2.8 units (0.028 inch), while the second ten coasted an average of 27 units (0.27 inch) with a standard deviation of 2.3 units (0.23 inch).

These coasting distance results are summarized in table 5.

Function	Dead-Band Width	Distance to Drill, feet
Shoulder left/right	± 20 units at 0.026 = 0.52 inch	6
Shoulder up/down	± 12 units at 0.026 = +0.31 inch	
Elbow up/down	± 20 units at 0.0177 = 0.35 inch	4.25
Wrist left/right	± 20 units at 0.010 = 0.20 inch	2.5
Wrist up/down	± 12 units at 0.0475 = 0.57 inch	

Table 5. Coasting distance results.

The overall accuracy, calculated for the control unit readings, was essentially the same as the measured accuracy (table 6), although the data were uncorrelated. This indicated that there was a problem in the control unit rather than in the manipulator.

Measured Overall Standard Deviation (measured with ruler and protractor, 20 trials)	Inches	Minutes of Arc
LEFT/RIGHT	0.057	
Up/down	0.092	
Vertical alignment	0.0	
Horizontal alignment	0.0	
Combined total	0.108	
Calculated Overall Standard Deviation (calculated from potentiometer readings)		
a. Up/down		
Shoulder up/down	0.040	2.0
Elbow up/down	0.027	1.9
Wrist up/down	0.057*	7.0*
Combined up/down standard deviation	0.075	
b. Left/right		
Shoulder left/right	0.058	2.9
Wrist left/right	0.046	5.8
Combined left/right standard deviation	0.074	
Calculated total (a + b) standard deviation	0.104	

*Should have been 0.015 inch and 1.9 minutes of arc.

Table 6. Manipulator accuracy.

POTENTIOMETER NOISE

A static measurement of potentiometer noise showed that a 4 mV, 60 Hz signal was present. This effectively degraded the data acquisition to 1 part in 4000 rather than 1 part in 16 000. The signal was found to be electromagnetic radiation from the WSP low-pressure hydraulic pump. This will not be a problem in the water, but better electromagnetic shielding is required for lab testing. (The wiring to the potentiometers consisted of shielded twisted pairs, but the potentiometers and electronics were not shielded.)

RISK FACTORS

Automatic tool interchange is not without disadvantages. System automation often results in added complexity and lower reliability. The principal source of concern in the automatic tool interchange study is the reliability of manipulator joint position sensors, which must work under the extreme ambient pressures of the deep ocean. The rest of the electronics, which are easier to house and protect, are felt to have a negligible impact on system reliability. For follow-on development, this problem would be minimized by employing good design, quality assurance measures, and comprehensive testing.

CONCLUSIONS

1. The feasibility of automatic tool interchange with a WSP comprising a compliant tool box and a compliant undersea manipulator was demonstrated in the laboratory.
2. Equipped with fixed-rate position control, the WSP performed automatic tool interchange repeatedly without malfunction.

RECOMMENDATIONS

1. Incorporate automation into the next work system that is built.
2. Ultimately, conduct in-water tests of the automated work system to verify its feasibility.

APPENDIX A: OPERATOR-MACHINE INTERFACE

This appendix lists some of the commands which an operator might wish to use during operation (table A1) and during programming (table A2).

It was not feasible to include all of these commands in this feasibility demonstration. Table A3 lists the commands which are available to an operator and table A4 lists the commands which are used to program a sequential operation.

Functional Inputs

1. Go to tool location xx and retrieve the yy tool (bit).
2. Store tool (bit) xx (which manipulator already has) into tool location yy.
3. Remember the present position of the manipulator and call it xx.
4. Go to the position which was previously tagged as xx.
5. Stow manipulator into a compact position for transport.
6. Unstow manipulator from transport position into work position.

Functional Outputs

1. Selected button is acknowledge (multifunction buttons acknowledged by multifunction display).
2. Error conditions displayed:
 - a. Manipulator does not respond (x seconds of "on" time does not produce y degrees of travel).
 - b. Manipulator overshoots desired location by x degrees.
 - c. Power-supply failures and other routine electronic malfunctions if not displayed elsewhere.
 - d. Hydraulic system failures not displayed elsewhere.

Table A1. Operation.

Functional Inputs

Program

1. The name of this sequence is x (x is a reference to console inputs).
2. Move the manipulator function x to the y position.
3. Continue to next step in the sequence.
4. Activate manipulator function x for y seconds.
5. End of sequence; turn off all manipulator functions. (TRANSFER)
6. Wait until all presently activated functions are complete, then go to next step in sequence.

Functional Outputs

Display inputs as required for next section.

1. Display program sequence y.
2. Display present position.
3. Display diagnostic information during execution of a sequence.

Table A2. Programming

Display Options

1. Display individual potentiometer reading.
2. Update potentiometer reading at ten samples per second.
3. Display all potentiometer readings.
4. Update all potentiometer readings.
5. Display a programmed sequence of commands.

Manipulator Operating Commands

1. Execute a preprogrammed sequence of operations. Name of operation will be displayed before and during operation.
2. Execute an operator-programmed sequence of operations. This does not have a name.
3. Display diagnostic information during operation.
4. The operation may be stopped any time.

Programming Commands

1. Any command listed in table A1 may be entered anywhere in the sequence.
2. Commands can be transferred from one location to another.
3. Entire command sequence (preprogrammed or programmed) can be inserted into the new sequence.
4. The present manipulator position may be automatically entered.

Table A3. Commands used by the operator.

Single Function Position Commands

1. Move shoulder up/down to XXXX OXXO.
2. Move shoulder left/right to XXXX OXXO.
3. Move elbow up/down to XXXX OXXO.
4. Move wrist up/down to XXXX OXXO.
5. Move wrist left/right to XXXX OXXO.
6. Operate hand open for 3.5 seconds.
7. Operate hand close for 3.5 seconds.

Multiple Function Position Commands

8. Extend/retract to XXXX OXXO.
(Operates either shoulder up and elbow down or shoulder down and elbow up by means of the shoulder up/down potentiometer.)
9. Extend for 3.5 seconds.
(Operates shoulder up and elbow down.)
10. Stop.

Table A4. Programming commands. Any number of these commands can be executed sequentially.

APPENDIX B: COMPUTER PROGRAM

ASM80 :F1:DACQ.ASY XREF PAGEWIDTH(72) PRINT(:LP:)

ISIS-II 8080/8085 MACRO ASSEMBLER, V4.0

DACQ

PAGE 1

LOC	OBJ	LINE	SOURCE STATEMENT
		1	NAME DACQ
		2	
		3	;PROGRAMMER: C. MORRIN
		4	;VERSION 2.1
		5	;DATE OF LAST CHANGE: OCTOBER 25, 1977
		6	
		7	;*****
		8	
		9	CSEG
		10	
		11	PUBLIC DISPOT,SETMUX,GETDAT,SAVE
		12	PUBLIC GETPOT,ADONLY
		13	EXTRN OUTPUT,FNASC,WAIT,HEXASC
		14	EXTRN OPINFO,MUXAD,PRADD
		15	
		16	;*****
		17	
		18	;DISPLAY POTENTIOMETER ROUTINE (DISPOT).
		19	;FUNCTION TO BE DISPLAYED IS IN REG A.
		20	;DISPOT GETS THE CURRENT VALUE OF THE POT,
		21	;AND OUTPUTS ' FF-XXXX' TO THE HAND CONTROLLER.
		22	
0000	C5	23	DISPOT: PUSH B
0001	E5	24	PUSH H
0002	4F	25	MOV C,A ;GET READY FOR SMUX
0003	CD5700	C	26 CALL SMUX
0006	CD9E00	C	27 CALL GETDAT
0007	CD3200	C	28 CALL SAVE
		29	;STORES DATA IN OPINFO+7 TO +10
000C	79	30	MOV A,C
		31	;FNASC REQUIRES FUNCTION IN ACC
000D	CD0000	E	32 CALL FNASC
		33	;ASCII FUNCTION IS NOW IN OPINFO+4,+5
		34	;OPINFO+3 IS ' ',OPINFO+6 IS '-'
0010	210300	E	35 LXI H,OPINFO+3
0013	0E08		36 MVI C,8
0015	CD0000	E	37 CALL OUTPUT ;' FF-XXXX'
0018	E1		38 POP H
0019	C1		39 POP B
001A	C9		40 RET
		41	
		42	;*****
		43	
001B	D5	44	GETPOT: PUSH D
001C	E5	45	PUSH H
001D	CD9200	C	46 CALL SETMUX
0020	CD9E00	C	47 CALL GETDAT
0023	EB		48 XCHG
0024	2A0000	E	49 LHLD PRADD
0027	23		50 INX H
0028	72		51 MOV M,D
0029	23		52 INX H
002A	73		53 MOV M,E
002B	EB	54	XCHG

LOC	OBJ	LINE	SOURCE STATEMENT
002C	CD3200 C	55	CALL SAVE
		56	;DATA WILL BE PUT INTO OPINFO+7 TO +10
002F	E1	57	POP H
0030	01	58	POP D
0031	C9	59	RET
		60	
		61	*****
		62	
		63	;SAVE DATA ROUTINE (SAVE):
		64	;DATA WILL BE PLACED IN OPINFO+7 TO +10
		65	;A/D DATA MUST BE IN REG HL
		66	
0032	F5	67	SAVE: PUSH PSW
0033	C5	68	PUSH B
0034	D5	69	PUSH D
0035	97	70	SUB A
0036	110700 E	71	LXI D,OPINFO+7
0039	0E04	72	MVI C,4H
003B	0604	73	TSFT4: MVI B,4H
		74	;TRIPLE SHIFT ACC AND HL FOUR PLACES
003D	29	75	DAD H
003E	17	76	RAL
003F	05	77	DCR B
0040	C23B00 C	78	JNZ TSFT4+2
0043	CD0000 E	79	CALL HEXASC
0046	12	80	STAX D ;STORE DATA IN OPINFO+7-10
0047	13	81	INX D
0048	0D	82	DCR C
0049	C23B00 C	83	JNZ TSFT4
004C	01	84	POP D
004D	C1	85	POP B
004E	F1	86	POP PSW
004F	C9	87	RET
		88	
		89	;ADONLY READS A/D AND SAVES DATA IN OPINFO+7-10
0050	CD9E00 C	90	ADONLY: CALL GETDAT
0053	CD3200 C	91	CALL SAVE
0056	C9	92	RET
		93	
		94	*****
		95	
		96	;SMUX ROUTINE
		97	;REQUIRES FUNCTION IN REG C
		98	;FORMAT: XXXXX000 = SU
		99	; XXXXX001 = SL
		100	; XXXXX010 = EU
		101	; XXXXX011 = EE
		102	; XXXXX100 = WU
		103	; XXXXX101 = WL
		104	; XXXXX110 = WR
		105	
		106	;MUX FORMAT (8255 REG C, ADDRESS = MUXAD+2)
		107	; 000XXXXX = SU = FUNCTION #1
		108	; 001XXXXX = EU = FUNCTION #2
		109	; 010XXXXX = SL = FUNCTION #3

LOC	OBJ	LINE	SOURCE STATEMENT		
		110 ;	011XXXXX	= WU	= FUNCTION #4
		111 ;	1XX00XXX	= WL	= FUNCTION #5
		112 ;	1XX01XXX	= ??	= FUNCTION #6
		113 ;	1XX10XXX	= ??	= FUNCTION #7
		114 ;	XXXXXXXXN	= A/D START	(N =NEG EDGE)
		115			
0057	F5	116	SMUX:	PUSH	PSW
005B	C5	117	PUSH	B	
0059	D5	118	PUSH	D	
005A	E5	119	PUSH	H	
005B	3E07	120	MVI	A,7	
005D	A1	121	ANA	C	
005E	0600	122	MVI	B,0	
0060	CAB300	C 123	JZ	DONE	;SU
0063	3D	124	DCR	A	
0064	0640	125	MVI	B,40H	
0066	CAB300	C 126	JZ	DONE	;SL
0069	0620	127	MVI	B,20H	
006B	3D	128	DCR	A	
006C	CAB300	C 129	JZ	DONE	;EU
006F	0600	130	MVI	B,0	
0071	3D	131	DCR	A	
0072	CAB300	C 132	JZ	DONE	;EE
0075	0660	133	MVI	B,60H	
0077	3D	134	DCR	A	
0078	CAB300	C 135	JZ	DONE	;HU
007B	0680	136	MVI	B,80H	
007D	3D	137	DCR	A	
007E	CAB300	C 138	JZ	DONE	;HL
0081	0690	139	MVI	B,90H	
0083	78	140	DONE:	MOV	A,B
0084	320200	E 141	STA	MUXAD+2	
0087	01C300	142	LXI	B,200	
008A	CD0000	E 143	CALL	WAIT	
		144	;WAIT 10MS FOR OP AMP TO SETTLE		
008D	E1	145	POP	H	
008E	D1	146	POP	D	
008F	C1	147	POP	B	
0090	F1	148	POP	PSW	
0091	C9	149	RET		
		150	*****		
		151	*****		
		152			
		153	;SETMUX SETS THE MULTIPLEXOR TO THE		
		154	;FUNCTION POINTED TO BY PRADD		
0092	E5	155	SETMUX:	PUSH	H
0093	C5	156	PUSH	B	
0094	2A0000	E 157	LHLD	PRADD	
0097	4E	158	MOV	C,M	
0098	CB5700	C 159	CALL	SMUX	
009B	C1	160	POP	B	
009C	E1	161	POP	H	
009D	C9	162	RET		
		163	*****		
		164	*****		

LOC	OBJ	LINE	SOURCE STATEMENT
		165	
		166	;GETDAT STARTS THE A/D CONVERTER,
		167	;THEN READS IT WHEN DONE
009E	F5	168	GETDAT: PUSH PSW
009F	C5	169	PUSH B
00A0	3E01	170	MVI A,1
00A2	320300	E	STA MUXAD+3
00A5	3E00	171	MVI A,0
00A7	320300	E	STA MUXAD+3 ;START A/D
00AA	010100	172	LXI B,1
00AB	CD0000	E	CALL WAIT
00B0	2A0000	E	LHLD MUXAD
00B3	C1	173	POP B
00B4	F1	174	POP PSW
00B5	C9	175	RET ;A/D DATA IS IN HL
		176	
		177	
		178	
		179	
		180	
		181	END

PUBLIC SYMBOLS

ADONLY C 0050	DISPOT C 0000	GETDAT C 009E	GETPOT C 001B
SAVE C 0032	SETMUX C 0092		

EXTERNAL SYMBOLS

FNASC E 0000	HEXASC E 0000	MUXAD E 0000	OPINFO E 0000
OUTPUT E 0000	PRADD E 0000	WAIT E 0000	

USER SYMBOLS

ADONLY C 0050	DISPOT C 0000	DONE C 0083	FNASC E 0000
GETDAT C 009E	GETPOT C 001B	HEXASC E 0000	MUXAD E 0000
OPINFO E 0000	OUTPUT E 0000	PRADD E 0000	SAVE C 0032
SETMUX C 0092	SMUX C 0057	TSFT4 C 003B	WAIT E 0000

ASSEMBLY COMPLETE, NO ERRORS

ISIS-II ASSEMBLER SYMBOL CROSS REFERENCE, V2.1

PAGE 1

ADONLY	12	90*
OACQ	1	
DISPOT	11	23*
UNONE	123	126 129 132 135 138 140*
FNASC	13	32
GETDAT	11	27 47 90 168*
GETPOT	12	44*
HEXASC	13	79
MUXAD	14	141 171 173 176
OPINFO	14	35 71
OUTPUT	13	37
PRADD	14	49 157
SAVE	11	28 55 67* 91
SETMUX	11	46 155*
SMUX	26	116* 159
TGFT4	73*	78 83
WAIT	13	143 175

CROSS REFERENCE COMPLETE

ISIS-II 2080/8085 MACRO ASSEMBLER, V4.0

DELAY PAGE 1

LOC	OBJ	LINE	SOURCE STATEMENT
		1	NAME DELAY
		2	
		3	;PROGRAMMER: C.MORRIN
		4	;VERSION 1.0
		5	;DATE OF LAST CHANGE: OCTOBER 31, 1977
		6	
		7	;VARIABLE DELAY ROUTINE
		8	;REGISTER BC CONTAINS DELAY
		9	;DELAY = 50 MICROSECONDS X (BC)
		10	
		11	;IMPLEMENTATION: RTC#1 LOADED WITH DELAY.
		12	;WHEN FINISHED RTC#2 SENDS SIGNAL
		13	;TO 8259 INTERRUPT CHIP WHICH CALLS
		14	;INITIAL ROUTINE WHICH JUMPS TO "WAIT1".
		15	;WAIT2" IS THE WAITING PLACE
		16	;DURING THE COUNTDOWN.
		17	
		18	CSEG
		19	
		20	PUBLIC WAIT,WAIT1
		21	EXTRN RTCAD,INTAD,WFLAG
		22	
0000 E5		23	WAIT: PUSH H
0001 D5		24	PUSH D
0002 F5		25	PUSH PSW
0003 210300 E		26	LXI H,RTCAD+3 ;BC CONTAINS DELAY
0006 3670		27	MVI M,70H ;SET RTC1 TO MODE 0
0008 2B		28	DCX H
0009 2B		29	DCX H
000A 71		30	MOV M,C ;LOAD RTC#1 = REG BC
000B 70		31	MOV M,B
000C F3		32	DI
000D 210100 E		33	LXI H,INTAD+1
0010 5E		34	MOV E,M ;GET CURRENT MASK
0011 36BF		35	MVI M,0BFH ;MASK ALL BUT RTC1
0013 2B		36	DCX H
0014 36B5		37	MVI M,85H ;OCW2: RTC#1 TOP PRIORITY
0016 3E01		38	MVI A,1
0018 320000 E		39	STA WFLAG
001B FB		40	WAIT2: EI
001C 3A0000 E		41	LDA WFLAG
001F E6FF		42	ANI OFFH ;SET ACC FLAGS
0021 C21800 C		43	JNZ WAIT2 ;WAIT FOR RTC#1 INTERRUP
		T	
0024 F3		44	DI
0025 7B		45	MOV A,E ;GET SAVED MASK
0026 F640		46	ORI 40H ;MASK OUT RTC1
0028 210100 E		47	LXI H,INTAD+1
002B 77		48	MVI M,A ;OCW1: SET MASK
002C 2B		49	DCX H
002D 3666		50	MVI M,66H ;OCW2: END OF RTC1 INT
002F 3684		51	MVI M,84H ;OCW2: UART TOP PRIORITY
0031 F1		52	POP PSW
0032 D1		53	POP D

LOC	OBJ	LINE	SOURCE STATEMENT	
0033	E1	54	POP	H
0034	FB	55	EI	
0035	C9	56	RET	
		57		
0036	F5	58 ;+++++.....		
0037	3E00	59 WAIT1: PUSH PSW		
0039	320000 E	60 MVI A,0		
003D	F1	61 STA NFLAG		
003D	C9	62 POP PSW		
		63 RET		;RETURN TO WAIT2
		64		
		65 END		

PUBLIC SYMBOLS

WAIT C 0000 WAIT1 C 0036

EXTERNAL SYMBOLS

INTAD E 0000 RTCAD E 0000 NFLAG E 0000

USER SYMBOLS

INTAD E 0000 RTCAD E 0000 WAIT C 0000 WAIT1 C 0036
WAIT2 C 001B NFLAG E 0000

ASSEMBLY COMPLETE, NO ERRORS

ISIS-II ASSEMBLER SYMBOL CROSS REFERENCE, V2.1

PAGE 1

DELAY	1		
INTAD	21	33	47
RTCAD	21	26	
WAIT	20	238	
WAIT1	20	598	
WAIT2	408	43	
NFLAG	21	39	41 61

CROSS REFERENCE COMPLETE

ASMBD :F1:EPROMW.ASY XREF PAGewidth(72) PRINT(:LP:)

ISIS-II 3080/8085 MACRO ASSEMBLER, V4.0

EPROMW PAGE 1

LOC	OBJ	LINE	SOURCE STATEMENT
		1	NAME EPROMW
		2	
		3 ;PROGRAMMER: C. MORRIN	
		4 ;VERSION: 2.0W	
		5 ;DATE OF LAST CHANGE: NOVEMBER 7, 1977	
		6	
		7 ;*****	
		8	
		9 DSEG	
		10	
		11 PUBLIC H0,H1,H2,H3,H4	
		12 PUBLIC H5,H6,H7,H8,H9	
		13	
		14 ;*****	
		15 ;FUNCTION DEFINITIONS:	
		16	
0000		17 SU EQU 0	
0001		18 SL EQU 1	
0002		19 EU EQU 2	
0003		20 EE EQU 3	
0004		21 NU EQU 4	
0005		22 WL EQU 5	
0008		23 HO EQU 8	
0009		24 HC EQU 9	
000E		25 EX EQU 0EH	
		26	
00FF		27 STOP EQU OFFH	
		28	
		29 ;*****	
		30 ;PROG*AD=*	
		31 ;MOVE ARM TO NEUTRAL POSITION	
0000 00		32 HO: DB SU,6AH,44H,S	
0001 6A			
0002 44			
0003 05			
0004 01		33 DB SL,62H,88H,S	
0005 62			
0006 88			
0007 05			
0008 02		34 DB EU,2BH,0E4H,S	
0009 2B			
000A E4			
000B 05			
000C 04		35 DB NU,7EH,0DOH,S	
000D 7E			
000E D0			
000F 05			
0010 05		36 DB WL,7BH,0CCH,S	
0011 7B			
0012 CC			
0013 05			
0014 FF		37 DB STOP	
		38	
		39 ;+++++	

LOC	OBJ	LINE	SOURCE STATEMENT
		40	;PROG#AD= #1
		41	;GO TO TOOL #1:
0015	05	42 H1:	DB NL,7CH,34H,3
0016	7C		
0017	34		
0018	03		
0019	08	43	DB H0,0,0,0
001A	00		
001B	00		
001C	00		
001D	01	44	DB SL,8BH,0C0H,5
001E	8B		
001F	C0		
0020	05		
		45	
0021	00	46	DB SU,68H,84H,3
0022	68		
0023	84		
0024	03		
0025	02	47	DB EU,22H,74H,5
0026	22		
0027	74		
0028	05		
0029	04	48	DB WU,81H,50H,3
002A	81		
002B	50		
002C	03		
		49	
002D	03	50	DB EE,70H,0,3
002E	70		
002F	00		
0030	03		
0031	00	51	DB SU,78H,0B4H,3
0032	78		
0033	84		
0034	03		
0035	02	52	DB EU,38H,0B0H,5
0036	38		
0037	80		
0038	05		
		53	
0039	03	54	DB EE,7CH,0ACH,3
003A	7C		
003B	AC		
003C	03		
003D	00	55	DB SU,7EH,0ACH,3
003E	7E		
003F	AC		
0040	03		
0041	02	56	DB EU,43H,0B4H,5
0042	43		
0043	84		
0044	03		
		57	
0045	03	58	DB EE,81H,0,3

LOC	OBJ	LINE	SOURCE STATEMENT	
0046	81			
0047	00			
0048	03			
0049	00	59	DB	SU,83H,90H,3
004A	83			
004B	90			
004C	03			
004D	02	60	DB	EU,4CH,0BCH,5
004E	4C			
004F	BC			
0050	05			
0051	03	61		
0052	85	62	DB	EE,85H,0ACH,3
0053	AC			
0054	03			
0055	00	63	DB	SU,86H,0ACH,3
0056	86			
0057	AC			
0058	03			
0059	02	64	DB	EU,51H,88H,5
005A	51			
005B	88			
005C	05			
005D	01	65		
005E	88	66	DB	SL,BBH,0,7
005F	00			
0060	07			
0061	05	67	DB	HL,7AH,0,3
0062	7A			
0063	00			
0064	03			
0065	03	68		
0066	87	69	DB	EE,87H,0,3
0067	00			
0068	03			
0069	07	70	DB	HC,0,0,0
006A	00			
006B	00			
006C	00			
006D	0E	71	DB	EX,0,0,0
006E	00			
006F	00			
0070	00			
0071	FF	72	DB	STOP
0072	03	73		
0073	83			
0074	90			
0075	03			
		74		;+++++ 75 ;PROG#AD=**2 76 ;BACK AWAY FROM TOOL #1 (WITH OR WITHOUT TOOL) 77 H2: DB EE,83H,90H,3

LOC	OBJ	LINE	SOURCE STATEMENT	
0076	02	78	DB	EU,4CH,0BCH,5
0077	4C			
0078	BC			
0079	05	79		
007A	03	80	DB	EE,7EH,0CCH,3
007B	7E			
007C	CC			
007D	03			
007E	02	81	DB	EU,43H,0B4H,5
007F	43			
0080	84			
0081	05	82		
0082	03	83	DB	EE,70H,0,5
0083	70			
0084	00			
0085	05			
0086	FF	84	DB	STOP
		85		
		86		*****
		87		;PROG*ADU=*3
		88		;GO TO BIT #1 (WITH TOOL #1)
0087	01	89 H3:	DB	SL,6AH,0,7
0088	6A			
0089	00			
008A	07			
008B	05	90	DB	WL,75H,08H,3
008C	75			
008D	08			
008E	03	91		
008F	00	92	DB	SU,93H,4CH,3
0090	93			
0091	4C			
0092	03			
0093	02	93	DB	EU,3AH,0ACh,5
0094	3A			
0095	AC			
0096	05			
0097	04	94	DB	NU,79H,0ECH,3
0098	79			
0099	EC			
009A	03	95		
009B	01	96	DB	SL,6FH,90H,5
009C	6F			
009D	90			
009E	05			
009F	05	97	DB	WL,75H,08H,3
00A0	75			
00A1	08			
00A2	03			
00A3	04	98	DB	NU,7CH,0E4H,3
00A4	7C			

LOC	OBJ	LINE	SOURCE STATEMENT
00A5	E4		
00A6	03		
00A7	FF	99	DB STOP
		100	
		101	;+++++-----+-----+-----+-----+-----+-----+-----+
		102	;PROG#AD=:#4
		103	;MOVE TOOL+BIT TO METAL PLATE AND ALIGN
00AB	01	104 H4:	DB SL,60H,54H,5
00AC	60		
00AA	54		
00AB	05		
00AC	05	105	DB WL,7CH,8CH,5
00AD	7C		
00AE	8C		
00AF	05		
		106	
00B0	04	107	DB WU,9CH,4CH,4
00B1	9C		
00B2	4C		
00B3	04		
00B4	00	108	DB SU,80H,0ACH,3
00B5	B0		
00B6	AC		
00B7	03		
00B8	02	109	DB EU,3CH,68H,5
00B9	3C		
00BA	68		
00BB	05		
		110	
00BC	00	111	DB SU,64H,0ECH,3
00BD	64		
00BE	EC		
00BF	03		
00C0	02	112	DB EU,37H,0B4H,5
00C1	37		
00C2	B4		
00C3	05		
00C4	04	113	DB WU,70H,0FCH,3
00C5	70		
00C6	FC		
00C7	03		
		114	
00C8	03	115	DB EE,68H,70H,3
00C9	68		
00CA	70		
00CB	03		
00CC	00	116	DB SU,68H,70H,3
00CD	68		
00CE	70		
00CF	03		
00D0	02	117	DB EU,42H,8CH,5
00D1	42		
00D2	8C		
00D3	05		
		118	

LOC	OBJ	LINE	SOURCE STATEMENT	
		119	DB	STOP
		120		121 ;+++++*****
		122		123 //PROG*AD=*5
		123		124 //RETURN BIT \$1 TO TOOL RACK:
00D4	FF	124	H5:	DB NL,76H,0D8H,3
00D5	05			
00D6	76			
00D7	B8			
00D8	03			
00D9	01	125	DB	SL,6AH,0C0H,5
00DA	6A			
00DB	C0			
00DC	05			
		126		
00DD	00	127	DB	SU,99H,0E0H,3
00DE	99			
00DF	E0			
00E0	03			
00E1	02	128	DB	EU,42H,0ABH,5
00E2	42			
00E3	A8			
00E4	05			
00E5	04	129	DB	WU,78H,0,3
00E6	78			
00E7	00			
00E8	03			
		130		
00E9	01	131	DB	SL,6FH,0C0H,5
00EA	6F			
00EB	C0			
00EC	05			
00ED	04	132	DB	WU,7DH,0BCH,3
00EE	7D			
00EF	BC			
00F0	03			
		133		
00F1	05	134	DB	WL,75H,0ACH,3
00F2	75			
00F3	AC			
00F4	03			
00F5	04	135	DB	WU,7EH,50H,3
00F6	7E			
00F7	50			
00F8	03			
		136		
00F9	05	137	DB	WL,74H,14H,3
00FA	74			
00FB	14			
00FC	03			
00FD	04	138	DB	WU,7FH,6CH,3
00FE	7F			
00FF	6C			
0100	03			
		139		
0101	05	140	DB	WL,74H,14H,3

LOC	OBJ	LINE	SOURCE STATEMENT	
0102	74			
0103	14			
0104	03			
0105	04	141	DB	WU,7FH,6CH,3
0106	7F			
0107	6C			
0108	03			
0109	03	142		
010A	BD	143	DB	EE,8DH,0B0H,3
010B	B0			
010C	03			
010D	FF	144	DB	STOP
010E	01	145		
010F	5F	146	;+++++ 147 ;PROG*AD=%6	
0110	6C	148	;STORE TOOL #1 AFTER STORING BIT #1	
0111	03	149	H6:	DB SL,5FH,6CH,3
0112	05	150	DB	WL,7AH,0ECH,3
0113	7A			
0114	EC			
0115	03			
0116	04	151		
0117	9C	152	DB	NU,9CH,4CH,3
0118	4C			
0119	03			
011A	00	153	DB	SU,80H,0A0H,3
011B	80			
011C	AC			
011D	03			
011E	02	154	DB	EU,3CH,60H,5
011F	3C			
0120	68			
0121	05			
0122	00	155		
0123	68	156	DB	SU,60H,84H,3
0124	84			
0125	03			
0126	02	157	DB	EU,22H,74H,5
0127	22			
0128	74			
0129	05			
012A	04	158	DB	WU,B1H,50H,3
012B	B1			
012C	50			
012D	03			
012E	01	159		
012F	BB	160	DB	SL,80H,7CH,7
0130	7C			

LOC	OBJ	LINE	SOURCE STATEMENT	
0131	07			
0132	03	161	DB	EE,6EH,0,3
0133	6E	162		
0134	00			
0135	03			
0136	20	163	DB	SU,78H,0B4H,3
0137	78			
0138	B4			
0139	03			
013A	02	164	DB	EU,38H,0B0H,5
013B	38			
013C	B0			
013D	05			
013E	03	165	DB	EE,7CH,0ACH,3
013F	7C	166		
0140	AC			
0141	03			
0142	00	167	DB	SU,7EH,0CCH,3
0143	7E			
0144	CC			
0145	03			
0146	02	168	DB	EU,43H,0B4H,5
0147	43			
0148	B4			
0149	05			
014A	03	169		
014B	81	170	DB	EE,B1H,0,3
014C	00			
014D	03			
014E	00	171	DB	SU,B3H,90H,3
014F	83			
0150	70			
0151	03			
0152	02	172	DB	EU,4CH,0BCH,5
0153	4C			
0154	BC			
0155	05			
0156	0E	173		
0157	00	174	DB	EX,0,0,0
0158	00			
0159	00			
015A	08	175	DB	H0,0,0,0
015B	00			
015C	00			
015D	00			
015E	FF	176	DB	STOP
		177		
		178		
		179		*****
		180		STORE TOOL#1 FROM NEUTRAL
015F	05	181	H7:	DB NL,7CH,34H,5

LOC	OBJ	LINE	SOURCE STATEMENT	
0160	7C			
0161	34			
0162	05			
		182		
0163	00	183	DB	SU,68H,04H,3
0164	68			
0165	34			
0166	03			
0167	02	184	DB	EU,22H,74H,5
0168	22			
0169	74			
016A	05			
016B	04	185	DB	WU,81H,50H,3
016C	81			
016D	50			
016E	03			
		186		
016F	01	187	DB	SL,68H,7CH,7
0170	BB			
0171	7C			
0172	07			
		188		
0173	03	189	DB	EE,6EH,0,3
0174	6E			
0175	00			
0176	03			
0177	00	190	DB	SU,78H,0B4H,3
0178	78			
0179	B4			
017A	03			
017B	02	191	DB	EU,3BH,0B0H,5
017C	38			
017D	B0			
017E	05			
		192		
017F	03	193	DB	EE,7CH,0ACH,3
0180	7C			
0181	AC			
0182	03			
0183	00	194	DB	SU,7EH,0CCH,3
0184	7E			
0185	CC			
0186	03			
0187	02	195	DB	EU,43H,084H,5
0188	43			
0189	B4			
018A	05			
		196		
018B	03	197	DB	EE,B1H,0,3
018C	81			
018D	00			
018E	03			
018F	00	198	DB	SU,83H,90H,3
0190	83			
0191	90			

LOC	OBJ	LINE	SOURCE STATEMENT	
0192	03			
0193	02	199	DB	EE,4CH,0BCH,5
0194	4C			
0195	8C			
0196	05			
		200		
0197	0E	201	DB	EX,0,0,0
0198	00			
0199	00			
019A	00			
019B	08	202	DB	HO,0,0,0
019C	00			
019D	00			
019E	00			
019F	FF	203	DB	STOP
		204		
		205	;PUSH TOOL #1 IN AFTER STORING	
01A0	03	206	DB	EE,03H,90H,3
01A1	33			
01A2	90			
01A3	03			
01A4	02	207	DB	EU,4CH,0BCH,5
01A5	4C			
01A6	8C			
01A7	05			
01A8	04	208	DB	EE,7EH,0CCH,3
01A9	7E			
01AA	CC			
01AB	03			
01AC	02	209	DB	EU,43H,0B4H,5
01AD	43			
01AE	B4			
01AF	05			
		210		
01B0	03	211	DB	EE,7AH,74H,3
01B1	7A			
01B2	74			
01B3	03			
01B4	09	212	DB	HC,0,0,0
01B5	00			
01B6	00			
01B7	00			
01B8	02	213	DB	EU,3CH,18H,5
01B9	3C			
01BA	18			
01BB	05			
01BC	04	214	DB	HU,79H,0C0H,3
01BD	79			
01BE	C0			
01BF	03			
		215		
01C0	03	216	DB	EE,7CH,0FBH,3
01C1	7C			
01C2	FB			
01C3	03			

LOC	OBJ	LINE	SOURCE STATEMENT	
01C4	00	217	DB	SU,7DH,0FBH,3
01C5	7D			
01C6	FE			
01C7	03			
01C8	02	218	DB	EU,41H,14H,5
01C9	41			
01CA	14			
01CB	05			
01CC	03	219 220	DB	EE,70H,0,3
01CD	70			
01CE	00			
01CF	03			
01D0	FF	221 222	DB	STOP
01D1	FF	223 H9:	DB	0FFH,0FFH,0FFH,0FFH
01D2	FF			
01D3	FF			
01D4	FF			
01D5	FF	224 225 226	DB	STOP END

PUBLIC SYMBOLS

H0	D 0000	H1	D 0015	H2	D 0072	H3	D 0087
H4	D 00AB	H5	D 00B5	H6	D 010E	H7	D 015F
H8	D 01A0	H9	D 01B1				

EXTERNAL SYMBOLS

USER SYMBOLS

EE	A 0003	EU	A 0002	EX	A 000E	H0	D 0000
H1	D 0015	H2	D 0072	H3	D 0087	H4	D 00AB
H5	D 00B5	H6	D 010E	H7	D 015F	H8	D 01A0
H9	D 01B1	HC	A 0009	H0	A 0008	SL	A 0001
STOP	A 00FF	SU	A 0000	WL	A 0005	WU	A 0004

ASSEMBLY COMPLETE, NO ERRORS

TIG-II ASSEMBLER SYMBOL CROSS REFERENCE, V2.1 PAGE 1

EE	20\$	50	54	58	62	69	77	80	83
	113	143	162	166	170	189	193	197	206
	208	211	216	220					
EPRONW	1								
EU	17\$	34	47	52	56	60	64	78	81
	93	109	112	117	120	154	157	164	168
	172	184	191	195	199	207	209	213	218
EX	25\$	71	174	201					
H0	11	32\$							
H1	11	42\$							
H2	11	77\$							
H3	11	89\$							
H4	11	104\$							
H5	12	124\$							
H6	12	149\$							
H7	12	181\$							
H8	12	206\$							
H9	12	223\$							
HC	24\$	70	212						
H0	23\$	43	175	202					
SL	18\$	33	44	66	89	96	104	125	131
	149	160	187						
STOP	27\$	37	72	84	99	119	144	176	203
	221	224							
SU	17\$	32	46	51	55	59	63	72	108
	111	116	127	153	156	163	167	171	183
	170	194	198	217					
NL	22\$	36	42	67	90	97	105	124	134
NU	137	140	150	181					
	21\$	35	48	94	98	107	113	129	132
	135	138	141	152	158	185	214		

CROSS REFERENCE COMPLETE

ISIS-II 8080/8085 MACRO ASSEMBLER, V4.0

EXECW PAGE 1

LOC	OBJ	LINE	SOURCE STATEMENT
		1	NAME EXECW
		2	
		3	;PROGRAMMER: C. MORRIN
		4	;VERSION 2.0W
		5	;DATE OF LAST CHANGE: OCTOBER 31, 1977
		6	
		7	;*****
		8	
		9	PUBLIC RTCAD,MUXAD,RELAY1,RELAY2
		10	PUBLIC EXEC,INTAD,START1,USRT
		11	PUBLIC DIRFLG,ARELAY,OVRFLG,STATE
		12	PUBLIC PRADD,OPINFO,WFLAG,POTFLG
		13	PUBLIC FINAL,CUTOFF,DISPFG,TAD
		14	PUBLIC COUNT,STOPFG
		15	EXTRN WAIT,WAIT1
		16	EXTRN INPUT,OUTPUT,INPT1
		17	
		18	
		19	DSEG
		20	
		21	;*****
		22	;SYSTEM OUTPUT PORT DEFINITION:
		23	;OUTPUT PORTS ARE MEMORY MAPPED:
F900		24	RTCAD EQU 0F900H ;8253 REAL TIME CLOCK
F400		25	MUXAD EQU 0F400H ;MULTIPLEXER, A/D CONTROL
FB00		26	RELAY1 EQU 0FB00H ;RELAY CONTROL
F500		27	RELAY2 EQU 0F500H ;RELAY CONTROL
FC00		28	INTAD EQU 0FC00H ;8259 INTERRUPT CONTROLE
	R		R
F800		29	USRT EQU 0F800H ;8251 USART ADDRESS
		30	
		31	;*****
		32	;SYSTEM MEMORY DEFINITION:
F000		33	DIRFLG EQU 0F000H ;SEE OPERAT
F001		34	ARELAY EQU DIRFLG+1 ;SEE RELAY
F003		35	OVRFLG EQU ARELAY+2 ;SEE OPERAT
F004		36	STATE EQU OVRFLG+1 ;SEE INPUT
F006		37	PRADD EQU STATE+2 ;SEE PROGRM
F008		38	OPINFO EQU PRADD+2 ;SEE PROGRM
F016		39	WFLAG EQU OPINFO+14 ;SEE DELAY
F017		40	POTFLG EQU WFLAG+1 ;SEE DACQ
F019		41	FINAL EQU POTFLG+2 ;SEE OPERAT
F01B		42	CUTOFF EQU FINAL+2 ;SEE OPERAT
F01D		43	DISPFG EQU CUTOFF+2 ;SEE OPERAT
F01E		44	TAD EQU DISPFG+1 ;SEE PROGRM
F020		45	COUNT EQU TAD+2 ;SEE OPERW
F021		46	STOPFG EQU COUNT+1 ;SEE OUTPUT
		47	;STOPFG IS 1 BYTE
		48	
		49	;*****
		50	;OUTPUT MESSAGES:
		51	
0000	2050524F	52	DTABLE: DB ' PROGRAM=P OPERATE=0'
0004	4752414D		

LOC	OBJ	LINE	SOURCE STATEMENT
0008	3D50204F		
000C	50455241		
0010	54453D4F		
0014	2052442A	53	OTABL1: DB ' RD*POTS=R DISPLAY=D'
0018	504F5453		
001C	3D522044		
0020	4953504C		
0024	41593D44		
0014		54	LTABLE EQU 20
0014		55	LTABL1 EQU 20
		56	
		57	;*****
		58	
		59	CSEG
		60	
		61	;EXEC ROUTINE:
		62	;EXEC PROVIDES A WAITING PLACE WHEN NEEDED
0000	F3	63	EXEC: DI
0001	2101FC	64	LXI H, INTAD+1
0004	7E	65	MOV A,M
0005	E6DF	66	ANI ODFH
0007	77	67	MOV M,A
0008	FB	68	EI
0009	00	69	NOP
000A	00	70	NOP
000B	00	71	NOP
000C	C30000 C	72	JMP EXEC
		73	
		74	;*****
		75	
		76	;INITIALIZATION ROUTINE
		77	
		78	;THIS ROUTINE INITIALIZES ALL HARDWARE
		79	; AND SOFTWARE INCLUDING:
80	;	8080 STACK POINTER	
81	;	8251 USRT	
82	;	8253 REAL TIME CLOCK	
83	;	8255 DATA ACQUISTION INTERFACE	
84	;	8255 RELAY INTERFACE	
85	;	8259 INTERRUPT CONTROLLER	
86	;	STATE	
87	;	PRADD	
88	;	OPINFO (HYPHENS AND SPACES ONLY)	
89	;	OVRFLG (OPERAT ROUTINE)	
90	;	HAND CONTROLLER DISPLAY	
91	;		
92	;	INITIAL ROUTINE INITIALIZES AFTER A	
93	;	POWER ON RESET OR A SOFTWARE RESET.	
94	;	8253 USES COUNTER 0 TO DIVIDE THE 2MHZ CLOCK TO	
95	;	19 KHZ TO DRIVE COUNTERS 1 AND 2 PLUS THE USRT	
96	;	COUNTER 1 IS THE RTC. COUNTER 2 IS NOT USED.	
97	;		
98	;	8255 DATA ACQUISTION INTERFACE INPUTS A/D DATA	
99	;	ON PORTS A AND B. IT CONTROLS THE A/D START	

LOC	OBJ	LINE	SOURCE STATEMENT
		100	; AND THE MULTIPLEXORS ON PORT C.
		101	;
		102	;ALL EXCEPT RXRDY ARE MASKED
		103	;
		104	;VECTOR ROUTINE VECTORS INTERRUPTS FROM 8259 TO
		105	;PROPER SUBROUTINES
		106	;
		107	;EXEC PROVIDES A WAITING PLACE WHEN REQUIRED
		108	
		109	ASEG
		110	
0000		111	ORG OH
0000 F3		112	START: DI
		113	
0001	31FFF0	114	;STACK POINTER INITIALIZATION:
		115	LXI SP,0F0FFH
		116	
0004	2103F9	117	;8253 (REAL TIME CLOCK) INITIALIZATION
		118	LXI H,RTCAD+3
0007	3616	119	MVI M,16H ;RTC#0 = MODE 3,LSB ONLY
0009	3670	120	MVI M,70H ;RTC#1 = MODE 0
0008	36AA	121	MVI M,0AAH ;RTC#2 = MODE 5,MSB ONLY
000D	2100F9	122	LXI H,RTCAD
0010	366A	123	MVI M,106 ;RTC#0 = 19.32 KHZ
		124	;NOTE: RTC#1 SET BY DELAY ROUTINE (WAIT)
		125	; RTC#2 NOT USED
		126	
0012	2103F4	127	;8255 (I/O PORT) INITIALIZATION
		128	LXI H,MUXAD+3
0015	3692	129	;PORTS A&B = INPUT (A/D)
		130	MVI M,92H
		131	;PORT C = OUTPUT (MUX,A/D)
		132	
0017	C30F00	133	JMP START2
		134	
		135	*****
		136	
		137	;THE FOLLOWING TABLE IS CALLED BY
		138	;THE 8259 INTERRUPT CONTROLLER
		139	
		140	ASEG
		141	
0020		142	ORG 20H
0020 C9		143	RET
		144	
0024		145	ORG 24H
0024 C9		146	RET
		147	
0028		148	ORG 28H
0028 C9		149	RET
		150	
002C		151	ORG 2CH
002C C9		152	RET
		153	
0030		154	ORG 30H

LOC	OBJ	LINE	SOURCE STATEMENT		
		155	RET	;TXRDY INTERRUPT	
		156			
0034		157	ORG	34H	
0034	F3	158	DI		
0035	C30000	E	JMP	INPUT	;RXRDY INTERRUPT
		160			
0038		161	ORG	38H	
0038	F3	162	DI		
0039	C30000	E	JMP	WAIT1	;RTC1 INTERRUPT
		163			
003C		164			
003C	C9	165	ORG	3CH	
		166	RET	;RTC2 INTERRUPT	
		167			
		168	*****		
		169	INITIALIZATION ROUTINE (CONTINUED)		
		170	;		
		171	CSEG		
		172			
		173			
		174	+++++		
		175	;8255 RELAY PORT INITIALIZATION:		
000F	3EB0	176	START2:	MVI	A,80H
0011	3203FD	177	STA	RELAY1+3 ;ALL PORTS = OUTPUT	
0014	3E00	178	MVI	A,0	
0016	3202FD	179	STA	RELAY1+2 ;TURN OFF RELAYS	
		180			
		181	+++++		
		182	;8259 (INTERRUPT CONTROLLER) INITIALIZATION		
0019	2100FC	183	LXI	H,INTAD	
001C	3636	184	MVI	M,36H ;ICW1: INTERVAL=4,	
001E	23	185	; START AT XX20H		
001F	3600	186	INX	H	
0021	36DF	187	MVI	M,0	
0023	2B	188	;ICW2: START AT 00XXH		
0024	3684	189	MVI	M,ODFH	
		190	;OCW1: MASK ALL BUT RXRDY (USRT)		
		191	DCX	H	
		192	MVI	M,B4H	
		193	;OCW2: INPUT HAS HIGHEST PRIORITY		
		194			
		195	+++++		
0026	2101F8	196	;8251 (USRT) INITIALIZATION		
0029	3641	197	LXI	H,USRT+1	
002B	3601	198	MVI	M,41H ;IF 1ST, SET MODE=ASYNC	
002D	3640	199		;IF 2ND, RESET	
002F	367A	200	MVI	M,01H ;IF 2ND, HARNESS	
		201		;IF 1ST, SET MODE=ASYNC	
		202	MVI	M,40H ;2ND: RESET 8251	
		203	MVI	M,7AH ;MODE = 1 STOP BIT,	
		204	;EVEN PARITY, PARITY ENABLE, 7 BIT CHARACTER,		
		205	; 16X CLK		
		206	MVI	M,17H ;COMMAND = NO HUNT,	
		207	; NO RESET, NO RTS, ERROR RESET,		
		208	; NO BREAK CHAR, RECEIVE ENABLE,		
		209	;ENABLE DATA TERMINAL READY (DTR = LOW),		

LOC	OBJ	LINE	SOURCE STATEMENT
		210	; TRANSMIT ENABLE
		211	
		212	;+++++;+++++;+++++;+++++;+++++;+++++;+++++;+++++
		213	;INITIALIZE OPINFO TABLE
0033	3E20	214	MVI A,' '
0035	3208F0	215	STA OPINFO
0038	320BF0	216	STA OPINFO+3
003B	3E2D	217	MVI A,'-'
003D	320EF0	218	STA OPINFO+6
0040	3213F0	219	STA OPINFO+11
		220	
		221	;+++++;+++++;+++++;+++++;+++++;+++++;+++++;+++++
		222	;INITIALIZE OVRFLG
0043	3E00	223	MVI A,0
0045	3203F0	224	STA OVRFLG
		225	
		226	;+++++;+++++;+++++;+++++;+++++;+++++;+++++;+++++
		227	;INITIALIZE HAND CONTROLLER DISPLAY
004B	211400	D	228 LXI H,OTABL1
004B	0E14		229 MVI C,LTABL1
004D	CD0000	E	230 CALL OUTPUT ;' RD*POTS=R DISPLAY=D'
0050	01204E		231 LXI B,20000
0053	CD0000	E	232 CALL WAIT ;WAIT 1 SECOND
0056	210000	D	233 LXI H,OTABLE
0059	0E14		234 MVI C,LTABLE
005B	CD0000	E	235 CALL OUTPUT ;' PROGRAM=P OPERATE=0'
		236	
		237	;+++++;+++++;+++++;+++++;+++++;+++++;+++++;+++++
		238	;INITIALIZE STATE
005E	210000	E	239 LXI H,INPT1
0061	2204F0		240 SHLD STATE
		241	
		242	;+++++;+++++;+++++;+++++;+++++;+++++;+++++;+++++
		243	;INITIALIZE PRADD
0064	2107F0		244 LXI H,PRADD+1;INITIALIZE PRADD
0067	36F1		245 MVI M,0F1H ;PROGRAM MEMORY = F1XXH
		246	
		247	;+++++;+++++;+++++;+++++;+++++;+++++;+++++;+++++
		248	;INITIALIZE DISPFG
0069	3A1DF0		249 LDA DISPFG
006C	FE00		250 CPI 0
006E	CA0000	C	251 JZ EXEC ;DISPFG RESET
0071	FE0F		252 CPI OFH
0073	CA0000	C	253 JZ EXEC ;DISPFG SET
		254	;DISFLG NEEDS INITIALIZATION:
0076	3E00		255 MVI A,0
0078	321BF0		256 STA DISPFG
		257	;NO DIAGNOSTICS DURING OPERATION
007B	C30000	C	258 JMP EXEC
		259	
		260	;*****;*****;*****;*****;*****;*****;*****;*****
		261	;SOFTWARE RESET:
007E	01F401		262 START1: LXI B,500
0081	CD0000	E	263 CALL WAIT
		264	;WAIT 25MS FOR THE 8251 TO FINISH TRANSMITTING

LOC	OBJ	LINE	SOURCE STATEMENT
0084	C30000	265	JMP START
		266	
		267	END

PUBLIC SYMBOLS

ARELAY A F001	COUNT A F020	CUTOFF A F01B	DIRFLG A F000
DISPFG A F01D	EXEC C 0000	FINAL A F019	INTAD A FC00
MUXAD A F400	OPINFO A F008	OVRFLG A F003	POTFLG A F017
PRADD A F006	RELAY1 A FD00	RELAY2 A F500	RTCAD A F900
START1 C 007E	STATE A F004	STOPFG A F021	TAD A F01E
USRT A FB00	WFLAG A F016		

EXTERNAL SYMBOLS

INPT1 E 0000	INPUT E 0000	OUTPUT E 0000	WAIT E 0000
WAIT1 E 0000			

USER SYMBOLS

ARELAY A F001	COUNT A F020	CUTOFF A F01B	DIRFLG A F000
DISPFG A F01D	EXEC C 0000	FINAL A F019	INPT1 E 0000
INPUT E 0000	INTAD A FC00	LTABL1 A 0014	LTABLE A 0014
MUXAD A F400	OPINFO A F008	OTABL1 D 0014	OTABLE D 0000
OUTPUT E 0000	OVRFLG A F003	POTFLG A F017	PRADD A F006
RELAY1 A FD00	RELAY2 A F500	RTCAD A F900	START A 0000
START1 C 007E	START2 C 000F	STATE A F004	STOPFG A F021
TAD A F01E	USRT A FB00	WAIT E 0000	WAIT1 E 0000
WFLAG A F016			

ASSEMBLY COMPLETE, NO ERRORS

ISIS-II ASSEMBLER SYMBOL CROSS REFERENCE, V2.1

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ARELAY	11	34*	35			
COUNT	14	45*	46			
CUTOFF	13	42*	43			
DIRFLG	11	33*	34			
DISPFG	13	43*	44	249	256	
EXEC	10	63*	72	251	253	258
EXECW	1					
FINAL	13	41*	42			
INPT1	16	239				
INPUT	16	159				
INTAD	10	28*	64	183		
LTABLE1	55*	229				
LTABLE	54*	234				
MUXAD	9	25*	128			
OPINFO	12	38*	39	215	216	218
OTABL1	53*	228				
OTABLE	52*	233				
OUTPUT	16	230	235			
OVRFLG	11	35*	36	224		
POTFLG	12	40*	41			
PRADD	12	37*	38	244		
RELAY1	9	26*	177	179		
RELAY2	9	27*				
RTCAD	9	24*	118	122		
START	112*	265				
START1	10	262*				
START2	133	176*				
STATE	11	36*	37	240		
STOPFG	14	46*				
TAD	13	44*	45			
USR1	10	29*	197			
WAIT	15	232	263			
WAIT1	15	163				
WFLAG	12	39*	40			

CROSS REFERENCE COMPLETE

LOC	OBJ	LINE	SOURCE STATEMENT
		1	NAME INPUT
		2	
		3	;PROGRAMMER: C.MORRIN
		4	;VERSION 2.0
		5	;DATE OF LAST CHANGE: NOVEMBER 2, 1977
		6	
		7	*****
		8	
		9	CSEG
		10	
		11	PUBLIC INPUT,INPT1,ERROR,EXIT
		12	PUBLIC ASCHEX,ASCHX1
		13	EXTRN PROGR,OPER,DISP,RDPOT,ATTRIB
		14	EXTRN INTAD,USR1,STATE,WAIT
		15	EXTRN HEXASC,XMIT,START1
		16	
		17	*****
		18	
		19	;USART RECEIVER INTERFACE ROUTINE:
		20	
		21	;INPUT IS CALLED BY THE 8259 INTERRUPT CONTROLLER
		22	;WHEN THE 8251 RXRDY STATUS LINE INDICATES THAT
		23	;A CHARACTER HAS BEEN RECEIVED.
		24	
		25	;USR1 RECEIVER READY, JUMP TO ENTRY POINT
		26	;INDICATED BY ADDRESS POINTER "STATE":
0000	3A0100	E	27 INPUT: LDA USRT+1 ;GET STATUS
0003	E638		28 ANI 38H ;MASK FOR ERROR FIELD
0005	C21400	C	29 JNZ ERR
0008	2A0000	E	30 LHLD STATE
000B	3A0000	E	31 LDA USRT ;GET DATA
000E	FE1A		32 CPI 1AH ;"CONTROL Z"
0010	CA0000	E	33 JZ START1
0013	E9		34 PCHL
		35	*****
0014	3A0100	E	36 ;+++++
0017	E601		37 ERR: LDA USRT+1 ;GET STATUS AGAIN
0019	C21400	C	38 ANI 1 ;MASK ALL BUT TXRDY
		39 JNZ ERR	
		40 ;WAIT UNTIL DATA BUS BUFFER IS EMPTY	
		41 ;(IT WILL BE FULL IF TRANSMITTER IS GOING)	
001C	3E17		42 MVI A,17H
001E	320100	E	43 STA USRT+1 ;RESET 8251 ERROR FLAGS
0021	3A0000	E	44 LDA USRT ;CLEAR RECEIVER
0024	019001		45 LXI B,400
0027	CD0000	E	46 CALL WAIT
002A	3A0000	E	47 LDA USRT ;CLEAR RECEIVER AGAIN
002D	C34900	C	48 JMP ERROR
		49	*****
		50	*****
		51	;PROGRAM, OPERATE, DISPLAY, OR READ POTS?
0030	FF50		52 INPT1: CPI 50H ;COMPARE WITH 'P'
0032	CA0000	E	53 JZ PROGR

LOC	OBJ	LINE	SOURCE STATEMENT		
0035	FE4F	54	CPI	4FH	;COMPARE WITH '0'
0037	CA0000	E 55	JZ	OPER	
003A	FE44	56	CPI	'D'	
003C	CA0000	E 57	JZ	DISP	;JUMP TO DISPLAY ROUTINE
003F	FE52	58	CPI	'R'	
0041	CA0000	E 59	JZ	RDPOT	
0044	FE41	60	CPI	'A'	
0046	CA0000	E 61	JZ	ATTRIB	
		62	;+++++-----+-----+-----+-----+-----+-----+-----+-----+		
		63	;INCORRECT INPUT, IGNORE INPUT & AND RING BELL:		
0049	3E07	64	ERROR:	MVI A,7H	;RING BELL
004B	CD0000	E 65	CALL	XMIT	
004E	C35400	C 66	JMP	EXIT+3	
		67	;-----+-----+-----+-----+-----+-----+-----+-----+		
		68	;ALL ROUTINES WHICH ARE INDIRECTLY CALLED		
		69	;BY INPUT RETURN TO EXIT TO END THE INTERRUPT:		
0051	220000	E 70	EXIT:	SHLD STATE	;SET NEW STATE
0054	F3	71	DI		
		72	;8259 MUST RECEIVE END OF INTERRUPT BEFORE		
		73	;ALLOWING INPUT ROUTINE TO BE CALLED AGAIN:		
0055	3E65	74	MVI	A,65H	;OCW2: END OF INPUT INT
0057	320000	E 75	STA	INTAD	
005A	FB	76	EI		
005B	C9	77	RET		
		78	;-----+-----+-----+-----+-----+-----+-----+-----+		
		79	;ASCII TO HEXADECIMAL CONVERSION ROUTINES.		
		80	;-----+-----+-----+-----+-----+-----+-----+-----+		
		81	;ALL ROUTINES START AND END WITH DATA IN ACC		
		82	;ASCHEX = ASCII TO HEX (HEX: LOWER HALF ACC)		
		83	;ASCHX1 = ASCII TO HEX (HEX: UPPER HALF ACC)		
		84	;-----+-----+-----+-----+-----+-----+-----+-----+		
		85	;NOTE: ASCII TO HEX CONVERSIONS ALSO TRANSMIT		
		86	CHARACTER TO USRT (XMIT)		
		87	;-----+-----+-----+-----+-----+-----+-----+-----+		
005C	CD6800	C 88	ASCHEX:	CALL DATA	
005F	C9	89	RET		
		90	;-----+-----+-----+-----+-----+-----+-----+-----+		
0060	CD6800	C 91	ASCHX1:	CALL DATA	
0063	07	92	RLC		
0064	07	93	RLC		
0065	07	94	RLC		
0066	07	95	RLC		
0067	C9	96	RET		
		97	;-----+-----+-----+-----+-----+-----+-----+-----+		
		98	;DATA ROUTINE HANDLES ROUTINE INPUT OF		
		99	;HEXADECIMAL DATA IN ASCII FORMAT.		
		100	;DATA CONVERTS TO HEX AND THEN		
		101	;ECHOS BY CONVERTING THE HEX CODE		
		102	;BACK INTO ASCII.		
0068	CS	103	DATA:	PUSH B	

LOC	OBJ	LINE	SOURCE	STATEMENT
0069	FE30	109	CPI	30H
006B	DA9500	C 110	JC	RETURN
006E	FE3A	111	CPI	3AH ;'9' + 1
0070	DAB900	C 112	JC	NUMBER
0073	FE41	113	CPI	41H ;'A'
0075	DA9500	C 114	JC	RETURN
0078	FE47	115	CPI	47H ;'F' + 1
007A	DAB700	C 116	JC	LETTER
007D	FE61	117	CPI	61H ;SMALL 'A'
007F	DA9500	C 118	JC	RETURN
0082	FE67	119	CPI	67H ;SMALL 'F' + 1
0084	D29500	C 120	JNC	RETURN
0087	C609	121	LETTER:	ADI 9
0089	E60F	122	NUMBER:	ANI OFH
008B	47	123	MOV	B,A
008C	CD0000	E 124	CALL	HEX SC
008F	CD0000	E 125	CALL	XMI,
0092	78	126	MOV	A,B
0093	C1	127	POP	B
0094	C9	128	RET	
		129		
		130		;+++++-----+
0095	C1	131	RETURN:	POP B
0096	F1	132	POP	PSW ;POP RETURN ADDRESS
		133		;THIS RETURN ADDRESS SHOULD BE ASCHEX+3
		134		;OR ASCHX1+3
0097	F1	135	POP	PSW ;POP RETURN ADDRESS
		136		;THIS RETURN ADDRESS SHOULD BE = INPTXX+3
0098	C34900	C 137	JMP	ERROR
		138		;HOPEFULLY INPTXX DID NOT PUSH ANYTHING
		139		
		140		
		141		END

PUBLIC SYMBOLS

ASCHEX C 005C ASCHX1 C 0060 ERROR C 0049 EXIT C 0051
INPT1 C 0030 INPUT C 0000

EXTERNAL SYMBOLS

ATTRIB	E 0000	DISP	E 0000	HEXASC	E 0000	INTAD	E 0000
OPER	E 0000	PROGR	E 0000	RDPOT	E 0000	START1	E 0000
STATE	E 0000	USRT	E 0000	WAIT	E 0000	XMIT	E 0000

USER SYMBOLS

ASCHEX	C 005C	ASCHX1	C 0060	ATTRIB	E 0000	DATA	C 006B
DISP	E 0000	ERR	C 0014	ERROR	C 0049	EXIT	C 0051
HEXASC	E 0000	INPT1	C 0030	INPUT	C 0000	INTAD	E 0000
LETTER	C 0087	NUMBER	C 0089	OPER	E 0000	PROGR	E 0000
RDPOT	E 0000	RETURN	C 0095	START1	E 0000	STATE	E 0000
USR1	E 0000	WAIT	E 0000	XMIT	E 0000		

ASSEMBLY COMPLETE, NO ERRORS

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ASCHEX	12	92*
ASCHX1	12	95*
ATTRIB	13	61
DATA	92	95 108*
DISP	13	57
ERR	29	37* 39
ERROR	11	48 65* 137
EXIT	11	67 72*
HEXASC	15	124
INPT1	11	52*
INPUT	1	11 27*
INTAD	14	77
LETTER	116	121*
NUMBER	112	122*
OPER	13	55
PROGR	13	53
RDPUT	13	59
RETURN	110	114 118 120 131*
START1	15	33
STATE	14	30 72
USRT	14	27 31 37 43 44 47
WAIT	14	46
XMIT	15	66 125

CROSS REFERENCE COMPLETE

ISIS-II 8080/8085 MACRO ASSEMBLER, V4.0

OPERW PAGE 1

LOC	OBJ	LINE	SOURCE STATEMENT
		1	NAME OPERW
		2	
		3	;PROGRAMMER: C. MORRIN
		4	;VERSION 2.0W
		5	;DATE OF LAST CHANGE: NOVEMBER 3, 1977
		6	
		7	;*****
		8	
		9	CSEG
		10	
		11	PUBLIC OPER,ATTRIB,PROMT
		12	EXTRN ERROR,EXIT,XMIT,INTAD
		13	EXTRN OPINFO,MUXAD,ASCHEX,ASCHX1
		14	EXTRN OUTPUT,PRADD,DISPFG,WAIT
		15	EXTRN GETDAT,FINAL,CUTOFF,START1
		16	EXTRN SETMUX,RSTART,RSTOP,DIRFLG
		17	OVRFLG,DPROGM,DRSULT,COUNT
		18	EXTRN H0,H1,H2,H3,H4
		19	EXTRN H5,H6,H7,H8,H9
		20	
		21	;*****
		22	
		23	DSEG
		24	
		25	;OUTPUT MESSAGE TABLE:
0000	204F5045	26	OTAB1: DB 'OPER*AD='
0004	522A4144		
0008	3D		
0009	20474F20	27	OTAB2: DB ' GO = G'
000D	3D2047		
0010	20324E44	28	OTAB3: DB ' 2ND MISS: ABORT PROG'
0014	204D4953		
0018	533A2041		
001C	424F5254		
0020	2050524F		
0024	47		
0025	20464952	29	OTAB4: DB ' FIRST MISS'
0029	5354204D		
002D	495353		
0030	204F5045	30	OTAB5: DB ' OPER*DISP? YES OR NO'
0034	522A4449		
0038	53503F20		
003C	59455320		
0040	4F52204E		
0044	4F		
0045	205B5945	31	OTAB6: DB ' [YES] '
0049	535D20		
004C	205B4E4F	32	OTAB7: DB ' [NO] '
0050	5D20		
		33	
0009	34 LTAB1 EQU 9		
0007	35 LTAB2 EQU 7		
0015	36 LTAB3 EQU 21		
0008	37 LTAB4 EQU 11		

LOC	OBJ	LINE	SOURCE STATEMENT		
0015		38	L TAB5	EQU	21
0007		39	L TAB6	EQU	7
0006		40	L TAB7	EQU	6
		41			
		42	*****		
		43			
		44	!PROM ADDRESS TABLE:		
0052 0000	E	45	PROMT:	DW	H0,H1,H2,H3,H4
0054 0000	E				
0056 0000	E				
0058 0000	E				
005A 0000	E				
005C 0000	E	46		DW	H5,H6,H7,H8,H9
005E 0000	E				
0060 0000	E				
0062 0000	E				
0064 0000	E	47			
		48	*****		
		49			
		50	!ADDRESS TABLE FOR TOOL NAMES		
0066 7A00	D	51	SUTADD:	DW	TOOL00,TOOL01,TOOL02,TOOL03
0068 8900	D				
006A 9800	D				
006C A700	D				
006E B600	D	52		DW	TOOL04,TOOL05,TOOL06,TOOL07
0070 C500	D				
0072 D400	D				
0074 E300	D				
0076 F200	D	53		DW	TOOL08,TOOL09
0078 0101	D				
		54			
		55	!TOOL NAMES		
007A 53544F57		56	TOOL00:	DB	'STOW MANIPULTR'
007E 20204D41					
0082 4E495055					
0086 4C5452					
0089 474F2054		57	TOOL01:	DB	'GO TO TOOL #1'
008D 4F202020					
0091 544F4F4C					
0095 202331					
0098 4D4F5645		58	TOOL02:	DB	'MOVE FROM BOX'
009C 20202046					
00A0 524F4B20					
00A4 424F58					
00A7 474F2054		59	TOOL03:	DB	'GO TO BIT #1'
00AB 4F202020					
00AF 2C424954					
00B3 202331					
00B6 474F2054		60	TOOL04:	DB	'GO TO WORK AREA'
00BA 4F20574F					
00BE 524B2041					
00C2 524541					
00C5 53544F52		61	TOOL05:	DB	'STORE BIT #1'
00C9 45202020					

LOC	OBJ	LINE	SOURCE STATEMENT
00CD	20424954		
00D1	202331		
00D4	42495423	62	TOOL06: DB 'BIT#1 TO TOOL#1'
00DB	3120544F		
00DC	20544F4F		
00E0	4C2331		
00E3	53544F52	63	TOOL07: DB 'STORE TOOL #1'
00E7	45202020		
00EB	544F4F4C		
00EF	202331		
00F2	50555348	64	TOOL08: DB 'PUSH TOOL #1'
00F6	20202020		
00FA	544F4F4C		
00FE	202331		
0101	54525920	65	TOOL09: DB 'TRY AGAIN'
0105	20202020		
0109	20204147		
010D	41494E		
		66	
		67	;*****
		68	
		69	;LINKAGE MANIPULATOR INTERFACE ROUTINE
		70	
		71	;THIS ROUTINE OPERATES SOLENOID VALVES ONLY
		72	;THERE IS NO PROVISION FOR MULTIPLE VALVE
		73	;OPERATION
		74	;WILL NOT OPERATE WSP LINEAR EXTEND)
		75	
		76	;THIS ROUTINE DOES THE FOLLOWING:
		77	;1. DETERMINE WHETHER ARM IS WITHIN DEADBAND,
		78	; ABOVE DEADBAND, OR BELOW DEADBAND.
		79	;2. IF WITHIN DEADBAND, CHANGE PROGRAM COUNTER,
		80	; AND GO TO STEP 1.
		81	;3. IF OUTSIDE DEADBAND, STORE SHUTOFF POSITION
		82	; IN REG BC, TURN ON APPROPRIATE SOLENOID AND
		83	; COMPARE A/D DATA TO REG BC.
		84	; WHEN SHUTOFF POSITION IS REACHED,
		85	; TURN OFF ALL SOLENOIDS.
		86	;4. WAIT FOR AN APPROPRIATE PERIOD,
		87	; THEN CHECK AGAIN.
		88	;5. IF OTAB30CT OCCURS, TRY ONCE MORE.
		89	;6. IF A SECOND OTAB300T OCCURS, OPERATOR IS
		90	; NOTIFIED AND OPERATION ABORTED.
		91	;7. IF WITHIN DEADBAND, DISPLAY RESULTS.
		92	;8. CHECK FOR END OF PROGRAM, AND EITHER
		93	; INCREMENT PROGRAM OR STOP.
		94	
		95	CSEG
		96	
		97	;+++++
		98	;OPERATE MODE, REQUEST ADDRESS INFORMATION:
0000	210300	D	99 OPER: LXI H,OTAB1 ;'OPERATE ADDRESS='
0003	0E09		100 MVI C,LTAB1
0005	CD0000	E	101 CALL OUTPUT
0008	210E00	C	102 LXI H,OPER1 ;CALL OPER1 NEXT

LOC	OBJ	LINE	SOURCE STATEMENT	
000B	C30000	E 103	JMP	EXIT
		104		
		105	;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++	
		106	;OPERATE MODE, FIRST ADDRESS DIGIT	
000E	320100	E 107	OPER1:	STA OPINFO+1
0011	FE2A	E 108	CPI	'*'
0013	CA2700	C 109	JZ	EPROM
0016	CB0000	E 110	CALL	ASCHX1
0019	320000	E 111	STA	PRADD
001C	3EF1	E 112	MVI	A,OF1H
001E	320100	E 113	STA	PRADD+1
0021	213000	C 114	LXI	H,OPER2
0024	C30000	E 115	JMP	EXIT
		116	;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++	
0027	CD0000	E 117	EPROM:	CALL XMIT ;ECHO
002A	216600	C 118	LXI	H,OPER4
002D	C30000	E 119	JMP	EXIT
		120	;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++	
		121	;OPERATE MODE, SECOND ADDRESS DIGIT	
0030	320200	E 122	OPER2:	STA OPINFO+2
0033	CD0000	E 123	CALL	ASCHEX
0036	210000	E 124	LXI	H,PRADD
0039	B6	E 125	ORA	M
003A	77	E 126	MOV	M,A
		127	;OPERATE ADDRESS STORED IN PRADD IN BINARY	
003B	210900	D 128	G0:	LXI H,OTAB2
003E	0E07	E 129	MVI	C,LTAB2
0040	CD0000	E 130	CALL	OUTPUT ;' GO=G'
0047	214900	C 131	G01:	LXI H,OPER3
0046	C30000	E 132	JMP	EXIT
		133	;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++	
		134	;OPERATE MODE, FIRST "GO" COMMAND	
0049	FE53	E 135	OPER3:	CPI 'S'
004B	CA0000	E 136	JZ	START1
004E	FE47	E 137	CPI	'G'
0050	C26000	C 138	JNZ	TSTOP
		139	;OPERATE MANIPULATOR, BUT FIRST ENABLE	
		140	;HAND CONTROLLER (EMERGENCY STOP)	
0053	F3	E 141	DI	
0054	3E65	E 142	MVI	A,65H
		143	;OCW2: END OF INPUT INTERRUPT	
0056	320000	E 144	STA	INTAD
0059	FB	E 145	EI	
005A	CDD000	C 146	CALL	OPERAT
005D	C30000	C 147	JMP	OPER
		148	;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++	
		149	;EMERGENCY STOP IF OPERATING,	
		150	;ERROR MESSAGE IF NOT:	
0060	CD0000	E 151	TSTOP:	CALL RSTOP
0063	C30000	E 152	JMP	ERROR
		153	;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++	
		154	;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++	
		155	;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++	
		156	;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++	
		157	;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++ ;+++++	

LOC	OBJ	LINE	SOURCE STATEMENT	
		158	;+++++HARDWIRED PROGRAM MODE, ADDRESS DIGIT	
0066	320200	E 160	OPER4:	STA OPINFO+2
0069	CD0000	E 161	CALL	ASCHEX
006C	07	162	RLC	
006D	SF	163	MOV E,A	;SAVE DIGIT X 2
006E	4F	164	MOV C,A	
006F	0600	165	MVI B,0	
0071	215200	D 166	LXI H,PROMT	
0074	09	167	DAD B	
		168	;REG H = PROGRAM ADDRESS	
0075	7E	169	MOV A,M	;GET ADDRESS
0076	320000	E 170	STA PRADD	;PUT IT AWAY
0079	23	171	INX H	
007A	7E	172	MOV A,M	;GET 2ND HALF
007B	320100	E 173	STA PRADD+1	;PUT IT AWAY
		174	;OUTPUT NAME OF TOOL REQUESTED:	
007E	210000	E 175	LXI H,OPINFO	
0081	0E04	176	MVI C,4	
0083	CD0000	E 177	CALL OUTPUT ;' *A '	
0086	3E3D	178	MVI A,'='	
0088	CD0000	E 179	CALL XMIT	
008B	3E20	180	MVI A,' '	
008D	CD0000	E 181	CALL XMIT	
0090	216600	D 182	LXI H,OUTADD	
0093	1600	183	MVI D,0	;E CONTAINS DIGIT X 2
0095	19	184	DAD D	
		185	;REG H = OUTPUT ADDRESS	
0096	5E	186	MOV E,M	
0097	23	187	INX H	
0098	56	188	MOV D,M	
0099	EB	189	XCHG	
009A	0EOF	190	MVI C,15	
009C	CD0000	E 191	CALL OUTPUT	
009F	C34300	C 192	JMP GO1	
		193	;*****	
		194	;*****	
		195		
00A2	213000	D 196	ATTRIB: LXI H,QTABS	
00A5	0E15	197	MVI C,LTAB5	
00A7	CD0000	E 198	CALL OUTPUT ;' OPER*DISP YES OR NO'	
00AA	218000	C 199	LXI H,OPER10	
00AD	C30000	E 200	JMP EXIT	
		201	;*****	
		202	;*****	
		203	;DISPLAY DIAGNOSTICS DURING OPERATION?	
00B0	FE59	204	OPER10: CPI 'Y'	
00B2	CABD00	C 205	JZ AYES	
00B5	FE4E	206	CPI 'N'	
00B7	CACD00	C 207	JZ ANO	
00BA	C30000	E 208	JMP ERROR	
		209	;*****	
00BD	214500	D 210	;*****	
00C0	0E07	211	AYES: LXI H,OTAB6	
		212	MVI C,LTAB6	

LOC	OBJ	LINE	SOURCE STATEMENT		
00C2	CD0000	E 213	CALL	OUTPUT	; ' YES'
00C5	3EOF	214	MVI	A,OFH	
00C7	320000	E 215	STA	DISPFG	
00CA	C30000	E 216	JMP	START1	
		217			
		218	;+++++=====+++++=====+++++=====		
00CD	214C00	D 219	AND:	LXI	H,OTAB7
00D0	0E06	220	MVI	C,LTAB7	
00D2	CD0000	E 221	CALL	OUTPUT	; ' NO'
00D5	3E00	222	MVI	A,0	
00D7	320000	E 223	STA	DISPFG	
00DA	C30000	E 224	JMP	START1	
		225			
		226	;=====		
		227			
		228	;INITIALIZE MULTIPLEXER		
00DD	2A0000	E 229	OPERAT: LHLD	PRADD	;CHECK FOR HAND
00E0	7E	230	MOV	A,M	
00E1	E60E	231	ANI	0EH	;MASK
00E3	FE0B	232	CPI	B	
00E5	CAE601	C 233	JZ	HAND	
00E8	FE0E	234	CPI	0EH	
00EA	CAE601	C 235	JZ	HAND	
00ED	CD0000	E 236	CALL	SETMUX	;SET MUX & WAIT 100 MS
00F0	3A0000	E 237	LDA	DISPFG	
00F3	E60F	238	ANI	OFH	;SET ZERO FLAG
00F5	CAF000	C 239	JZ	SKIP1	
00F8	CD0000	E 240	CALL	DPROGM	
		241			
		242	;IS DATA LARGER THAN POSITION + DEADBAND ?		
00FB	CD0002	C 243	SKIP1: CALL	GETBC	;BC = -(POS+DB)
00FE	CD0000	E 244	CALL	GETDAT	;HL = A/D DATA
0101	09	245	DAD	B	
0102	BA3701	C 246	JC	ABOVE	
		247			
		248	;IS DATA SMALLER THAN POSITION - DEADBAND ?		
0105	CD1A02	C 249	CALL	GETBCM	;BC = -(POS-DB)
0108	2A0000	E 250	LHLD	MUXAD	;DATA FROM PREVIOUS GETD
		AT			
0108	09	251	DAD	B	;HL = A/D-(POS-DB)
010C	B27301	C 252	JNC	BELOW	
010F	2A0000	E 253	LHLD	MUXAD	;WITHIN DEADBAND
0112	220000	E 254	SHLD	CUTOFF	;CUTOFF=FINAL
0115	220000	E 255	SHLD	FINAL	
		256			
		257	;=====		
		258	;END OF OPERAT ROUTINE:		
		259	;DISPLAY RESULTS, INCREMENT PROGRAM ADDRESS &		
		260	;DETERMINE IF END OF PROGRAM HAS BEEN REACHED.		
0118	3E00	E 261	ENDOP: MVI	A,0	
011A	320000	E 262	STA	OVRFLG	
011D	3A0000	E 263	LDA	DISPFG	
0120	E60F	264	ANI	OFH	;SET ZERO FLAG
0122	CA2B01	C 265	JZ	SKIP2	
0125	CD0000	E 266	CALL	DRSULT	

LOC	OBJ	LINE	SOURCE STATEMENT		
0128	2A0000	E 267	SKIP2:	LHLD	PRADD ;GET PROGRAM ADDRESS
012B	110400	268		LXI	D,4 ;INCREMENT PROGRAM
012E	19	269		DAD	D
012F	220000	E 270		SHLD	PRADD
0132	7E	271		MOV	A,M
0133	E6F0	272		ANI	OF0H ;GET END OF PROGRAM FLAG
0135	C0	273		RNZ	
0136	C3DD00	C 274		JMP	OPERAT
		275			
		276	+++++ ;OPERATE MANIPULATOR: A/D DATA IS LARGER.		
0139	3E01	277	ABOVE:	MVI	A,1
013B	320000	E 278		STA	DIRFLG
013E	CD0000	E 280		CALL	RSTART
0141	CD3602	C 281		CALL	RUN
0144	CD0000	E 282		CALL	RSTOP
0147	2A0000	E 283		LHLD	MUXAD
014A	220000	E 284		SHLD	CUTOFF ;SAVE FOR DRSULT
		285			
		286	;OPERATION COMPLETE, WAIT FOR ARM TO STOP		
014D	011027	287		LXI	B,10000 ;WAIT .5 SECOND
0150	CD0000	E 288		CALL	WAIT
		289			
		290	;CHECK FOR BAD POT READING:		
0153	CD0002	C 291		CALL	GETBC
0156	21FF0F	292		LXI	H,OFFFOH
0157	09	293		DAD	B
015A	44	294		MOV	B,H
015B	4D	295		MOV	C,L
015C	CD0000	E 296		CALL	GETDAT
015F	09	297		DAD	B
0160	DABD00	C 298		JC	OPERAT
		299			
		300	;IF OK, CHECK FOR OVERSHOOT:		
0163	CD1A02	C 301		CALL	GETBCM ;BC = -(POS-DB)
0166	CD0000	E 302		CALL	GETDAT ;HL = A/D DATA
0169	220000	E 303		SHLD	FINAL ;SAVE FOR DRSULT
016C	09	304		DAD	B ;HL = A/D-(POS-DB)
016D	D2AD01	C 305		JNC	OVRSH
		306			
		307	;MANIPULATOR IS WITHIN DEADBAND.		
0170	C31B01	C 308		JMP	ENDOP
		309			
		310	+++++ ;OPERATE MANIPULATOR: A/D DATA SMALLER.		
0173	3E00	311		ABOVE:	MVI A,0
0175	320000	E 312		STA	DIRFLG
0178	CD0000	E 313		CALL	RSTART
017B	CD4502	C 314		CALL	RUNM
017E	CD0000	E 315		CALL	RSTOP
0181	2A0000	E 316		LHLD	MUXAD
0184	220000	E 317		SHLD	CUTOFF
		318			
		319			
		320	;OPERATION COMPLETE, WAIT FOR ARM TO STOP		
0187	011027	321		LXI	B,10000 ;WAIT .5 SECONDS

LOC	OBJ	LINE	SOURCE STATEMENT	
018A	CD0000	E 322	CALL	WAIT
		323		
		324	;CHECK FOR BAD POT READING:	
018D	CD1A02	C 325	CALL	GETBCM
0190	211000	326	LXI	H,0010H
0193	09	327	DAD	B
0194	44	328	MOV	B,H
0195	4D	329	MOV	C,L
0196	CD0000	E 330	CALL	GETDAT
0199	09	331	DAD	B
019A	D2DD00	C 332	JNC	OPERAT
		333		
		334	;IF OK, CHECK FOR OVERTSHOOT:	
019B	CD0002	C 335	CALL	GETBC ;BC = -(POS+DB)
01A0	CD0000	E 336	CALL	GETDAT ;JHL = A/D DATA
01A3	220000	E 337	SHLD	FINAL ;SAVE FOR DRSULT
01A6	09	338	DAD	B ;JHL = A/D - (POS+DB)
01A7	DAAD01	C 339	JC	OVRSH1
		340		
		341	;MANIPULATOR IS WITHIN DEADBAND.	
01AA	C31801	C 342	JMP	ENDUP
		343		
		344	+++++ ;MANIPULATOR MISSED DEADBAND REGION	
01AD	3A0000	E 345	;MANIPULATOR MISSED DEADBAND REGION	
01B0	E6FF	346	OVRSH1:	LDA OVRFLG
01B2	C2D301	C 347	ANI	OFFH
		348	JNZ	OVRSH1
		349		
		350	;MISSED ON FIRST ATTEMPT, NOTIFY	
		351	;OPERATOR AND TRY AGAIN	
01B5	3E01	352	MVI	A,1
01B7	320000	E 353	STA	OVRFLG
01BA	3A0000	E 354	LDA	DISPFG
01BD	E60F	355	ANI	OFH
01BF	CABD00	C 356	JZ	OPERAT
01C2	CD0000	E 357	CALL	DPROGM
01C5	CD0000	E 358	CALL	DRSULT
01C8	212500	D 359	LXI	H,OTAB4
01CB	0E0B	360	MVI	C,LTAB4
01CD	CD0000	E 361	CALL	OUTPUT ;' FIRST MISS'
01DD	C3DD00	C 362	JMP	OPERAT
		363		
		364	+++++ ;MANIPULATOR HAS MISSED TWICE,	
01D3	3600	365	;MANIPULATOR HAS MISSED TWICE,	
01D5	CD0000	E 366	;ABORT OPERATION	
01D8	CD0000	E 367	OVRSH1:	MVI M,0
01DB	211000	D 368	CALL	DPROGM
01DE	0E15	369	CALL	DRSULT
01E0	CD0000	E 370	LXI	H,OTAB3
01E3	C30000	E 371	MVI	C,LTAB3
		372	CALL	OUTPUT ;'2ND MISS: ABORT PROG'
		373	JMP	START1
		374		
		375	+++++ ;HAND: LDA DISPFG	
01E6	3A0000	E 376	HAND:	LDA DISPFG

LOC	OBJ	LINE	SOURCE STATEMENT		
01E9	E60F	377	ANI	OFH	
01ED	CAF101	C 378	JZ	SKIP3	
01EE	CD0000	E 379	CALL	DPROGM	
01F1	CD0000	E 380	SK1P3:	CALL	RSTART
01F4	01FFFF	381	LXI	B,0FFFFH	
01F7	CD0000	E 382	CALL	WAIT ;WAIT 3 SEC	
01FA	CD0000	E 383	CALL	RSTOP	
01FD	C32B01	C 384	JMP	SKIP2	
		385			
		386	*****		
		387			
0200	2A0000	E 388	GETBC:	LHLD	PRADD
0203	23	389	INX	H	; (REG HL) = DATA (HIGH)
0204	46	390	MOV	B,M	
0205	23	391	INX	H	
0206	4E	392	MOV	C,M	
0207	23	393	INX	H	; (REG HL) = DEADBAND
0208	5E	394	MOV	E,M	
0209	1600	395	MVI	D,O	; DE = DEADBAND
		396	;DEADBAND HAS TO BE SHIFTED 4 PLACES:		
020B	EB	397	XCHG		
020C	29	398	DAD	H	; LEFT SHIFT REG HL
020D	29	399	DAD	H	
020E	29	400	DAD	H	
020F	29	401	DAD	H	
0210	09	402	DAD	B	; HL = POS+DB
		403	; A CARRY HERE IS AN ERROR		
0211	3E00	404	MVI	A,O	
0213	95	405	SUB	L	
0214	4F	406	MOV	C,A	
0215	3E00	407	MVI	A,O	
0217	9C	408	SBB	H	
0218	47	409	MOV	B,A	; BC = -(POS+DB)
0219	C9	410	RET		
		411	*****		
		412	*****		
		413			
021A	2A0000	E 414	GETBCM:	LHLD	PRADD
021D	23	415	INX	H	
021E	23	416	INX	H	
021F	3E00	417	MVI	A,O	
0221	96	418	SUB	M	
0222	4F	419	MOV	C,A	
0223	2B	420	DCX	H	
0224	3E00	421	MVI	A,O	
0226	9E	422	SBB	M	
0227	47	423	MOV	B,A	; BC = -POS
0228	23	424	INX	H	
0229	23	425	INX	H	
022A	5E	426	MOV	E,M	
022B	1600	427	MVI	D,O	
022D	EB	428	XCHG		; HL = DB/4
022E	29	429	DAD	H	
022F	29	430	DAD	H	
0230	29	431	DAD	H	

LOC	OBJ	LINE	SOURCE STATEMENT		
0231	29	432	DAD	H	;HL = DB
0232	09	433	DAD	B	;HL = -(POS-DB)
0233	44	434	MOV	B,H	
0234	40	435	MOV	C,L	
0235	C9	436	RET		;BC = -(POS-DB)
		437			
		438	*****		
		439	/* REAL TIME OPERATION ROUTINES */		
		440	*****		
		441			
		442	;REG B = POSITION INFORMATION		
		443	;REG D = ADDRESS OF SINGLE BIT COMMAND FOR A/D		
		444	;REG H = A/D DATA & DIFFERENCE		
		445			
0236	110300	E 446	RUN:	LXI	D,MUXAD+3
0239	3E00	447	MVI	A,0	
023B	320000	E 448	STA	COUNT	
023E	3E01	449	RUN1:	MVI	A,1
		450			
		451	;SET A/D START BIT HIGH:		
0240	12	452	STAX	D	; (7 CYCLES)
0241	3D	453	DCR	A	; (5 CYCLES)
		454			
		455	;A/D CONVERTER READY, GET DATA:		
0242	2A0000	E 456	LHLD	MUXAD	
		457	;PRIOR TO DATA READ: (10 CYCLES)		
		458	;TIME TO READ DATA: (6 CYCLES)		
		459			
		460	;RESET A/D START BIT LOW (STARTS A/D)		
0245	12	461	STAX	D	; (7 CYCLES)
0246	09	462	DAD	B	; (10 CYCLES)
0247	DA5702	C 463	JC	CNTDN	; (10 CYCLES)
024A	3A0000	E 464	LDA	COUNT	
024D	3C	465	INR	A	
024E	320000	E 466	STA	COUNT	
0251	FE0A	467	CPI	10	
0253	C23E02	C 468	JNZ	RUN1	
0256	C9	469	RET		
0257	3A0000	E 470	CNTDN:	LDA	COUNT
025A	3D	471	DCR	A	
025B	D25F02	C 472	JNC	CNTDN1	
025E	77	473	SUB	A	;DONT WANT MINUS NUMBERS
025F	320000	E 474	CNTDN1:	STA	COUNT
0262	C33E02	C 475	JMP	RUN1	
		476			
		477	;DATA READ TIME: 13 CYCLES OR 7 MICROSECONDS		
		478			
		479	;CONVERSION TIME: 47 CYCLES OR 23 MICROSECONDS		
		480			
		481	;TOTAL TIME: 60 CYCLES OR 30 MICROSECONDS		
		482			
		483	*****		
		484			
0265	110300	E 485	RUNM:	LXI	D,MUXAD+3
0268	3E00	486	MVI	A,0	

LOC	OBJ	LINE	SOURCE STATEMENT	
026A	320000	E 487	STA	COUNT
026D	3E01	488	MVI	A,1
026F	12	489	STAX	D
0270	3D	490	DCR	A
0271	2A0000	E 491	LHLD	MUXAD
0274	12	492	STAX	D
0275	09	493	DAD	B
0276	D2B602	C 494	JNC	CNTDNM
0279	3A0000	E 495	LDA	COUNT
027C	3C	496	INR	A
027D	320000	E 497	STA	COUNT
0280	FE0A	498	CPI	10
0282	C26D02	C 499	JNZ	RUNM1
0285	C9	500	RET	
0286	3A0000	E 501	CNTDNM:	LDA COUNT
0289	3D	502	DCR	A
028A	D2B602	C 503	JNC	CNT1
028D	97	504	SUB	A
028E	320000	E 505	CNT1:	STA COUNT
0291	C36D02	C 506	JMP	RUNM1
0294	C9	507	RET	
		508		
		509	*****	
		510	;* END REAL TIME OPERATION ROUTINES *	
		511	*****	
		512		
		513	END	

PUBLIC SYMBOLS

ATTRIB C 00A2 OPER C 0000 PRMT D 0052

EXTERNAL SYMBOLS

ASCHEX	E 0000	ASCHX1	E 0000	COUNT	E 0000	CUTOFF	E 0000
DIRFLG	E 0000	DISPFG	E 0000	DPROGM	E 0000	DRSULT	E 0000
ERROR	E 0000	EXIT	E 0000	FINAL	E 0000	GETDAT	E 0000
H0	E 0000	H1	E 0000	H2	E 0000	H3	E 0000
H4	E 0000	H5	E 0000	H6	E 0000	H7	E 0000
H8	E 0000	H9	E 0000	INTAD	E 0000	MUXAD	E 0000
OPINFO	E 0000	OUTPUT	E 0000	OVRFGLG	E 0000	PRADD	E 0000
RSTART	E 0000	RSTOP	E 0000	SETMUX	E 0000	START1	E 0000
WAIT	E 0000	XMIT	E 0000				

USER SYMBOLS

ABOVE	C 0139	ANO	C 00CD	ASCHEX	E 0000	ASCHX1	E 0000
ATTRIB	C 00A2	AYES	C 00BD	BELLOW	C 0173	CNT1	C 028E
CNTDN	C 0257	CNTDN1	C 025F	CNTDNM	C 0286	COUNT	E 0000
CUTOFF	E 0000	DIRFLG	E 0000	DISPFG	E 0000	DPROGM	E 0000
DRSULT	E 0000	ENDOP	C 0118	EPROM	C 0027	ERROR	E 0000
EXIT	E 0000	FINAL	E 0000	GETBC	C 0200	GETBCM	C 021A
GETDAT	E 0000	G0	C 003B	G01	C 0043	H0	E 0000
H1	E 0000	H2	E 0000	H3	E 0000	H4	E 0000
H5	E 0000	H6	E 0000	H7	E 0000	H8	E 0000
H9	E 0000	HAND	C 01E6	INTAD	E 0000	LTAB1	A 0009
LTAB2	A 0007	LTAB3	A 0015	LTAB4	A 000B	LTAB5	A 0015

ISIS-II 8080/8085 MACRO ASSEMBLER, V4.0

OPRN PAGE 12

LTAB6	A 0007	LTAB7	A 0006	MUXAD	E 0000	OPER	C 0000
OPER1	C 000E	OPER10	C 00B0	OPER2	C 0030	OPER3	C 0049
OPER4	C 0066	OPERAT	C 00D0	OPINFO	E 0000	OTAB1	D 0000
OTAB2	D 0009	OTAB3	D 0010	OTAB4	D 0025	OTAB5	D 0030
OTAB6	D 0045	OTAB7	D 004C	OUTADD	D 0066	OUTPUT	E 0000
OVRFLG	E 0000	OVRSH1	C 01D3	OVRSH1	C 01AD	PRADD	E 0000
PROMT	D 0052	RSTART	E 0000	RSTOP	E 0000	RUN	C 0236
RUN1	C 023E	RUNM	C 0265	RUNM1	C 026D	SETMUX	E 0000
SKIP1	C 00FB	SKIP2	C 0128	SKIP3	C 01F1	START1	E 0000
TOOL00	D 007A	TOOL01	D 0089	TOOL02	D 0098	TOOL03	D 00A7
TOOL04	D 00B6	TOOL05	D 00C5	TOOL06	D 00D4	TOOL07	D 00E3
TOOL08	D 00F2	TOOL09	D 0101	TSTOP	C 0060	WAIT	E 0000
XMIT	E 0000						

ASSEMBLY COMPLETE, NO ERRORS

ISIS-II ASSEMBLER SYMBOL CROSS REFERENCE, V2.1

PAGE 1

ABOVE	246	278*								
AND	207	219*								
ASCHEX	13	125	161							
ASCHX1	13	110								
ATTRIB	11	196*								
AYES	205	211*								
BELOW	252	312*								
CNTJ	503	505*								
CNTDN	463	470*								
CNTDN1	472	474*								
CNTDNM	494	501*								
COUNT	17	448	464	466	470	474	487	495	497	
	501	505								
CUTOFF	15	254	284	318						
DIRFLG	16	279	313							
DISPFG	14	215	223	237	263	354	376			
DPROGM	17	240	357	368	379					
DRSULT	17	266	358	369						
ENDOP	261*	308	342							
EPROM	109	118*								
ERROR	12	156	208							
EXIT	12	103	115	120	134	200				
FINAL	15	255	303	337						
GETBC	243	291	335	388*						
GETBCM	249	301	325	414*						
GETDAT	15	244	296	302	330	336				
GO	130*									
GO1	133*	192								
H0	18	45								
H1	18	45								
H2	18	45								
H3	18	45								
H4	18	45								
HS	19	46								
H6	19	46								
H7	19	46								
H8	19	46								
H9	19	46								
HAND	233	235	376*							
INTAD	12	147								
LTAB1	34*	100								
LTAB2	35*	131								
LTAB3	36*	371								
LTAB4	37*	360								
LTAB5	38*	197								
LTAB6	39*	212								
LTAB7	40*	220								
MUXAD	13	250	253	293	317	446	456	485	491	
OPER	11	99*	150							
OPER1	102	107*								
OPER10	199	204*								
OPER2	114	124*								
OPER3	133	138*								
OPER4	119	160*								
OPERAT	149	229*	274	298	332	356	362			
OPERNW	1									
OPINFO	13	107	124	160	175					

ISIS-II ASSEMBLER SYMBOL CROSS REFERENCE, V2.1

PAGE 2

OTAB1	26\$	99							
OTAB2	27\$	130							
OTAB3	28\$	370							
OTAB4	29\$	359							
OTAB5	30\$	196							
OTAB6	31\$	211							
OTAB7	32\$	219							
OUTADD	51\$	182							
OUTPUT	14	101	132	177	191	198	213	221	361
		372							
DVRFLG	17	262	346	353					
DVRSH1	348	367\$							
DVRSHT	305	339	346\$						
PRADD	14	111	113	126	170	173	229	267	270
	388	414							
PRONT	11	45\$	166						
RSTART	16	280	314	380					
RSTOP	16	155	282	316	383				
RUN	281	446\$							
RUN1	449\$	468	475						
RUNM	315	485\$							
RUNM1	488\$	499	506						
SETMUX	16	236							
SKIP1	239	243\$							
SKIP2	265	267\$	384						
SKIP3	378	380\$							
START1	15	139	216	224	373				
TOOL00	51	56\$							
TOOL01	51	57\$							
TOOL02	51	58\$							
TOOL03	51	59\$							
TOOL04	52	60\$							
TOOL05	52	61\$							
TOOL06	52	62\$							
TOOL07	52	63\$							
TOOL08	53	64\$							
TOOL09	53	65\$							
TSTOP	141	155\$							
WAIT	14	288	322	382					
XMIT	12	118	179	181					

CROSS REFERENCE COMPLETE

ISIS-II 8080/8085 MACRO ASSEMBLER, V4.0

OUTPUT PAGE 1

LOC	OBJ	LINE	SOURCE STATEMENT
		1	NAME OUTPUT
		2	
		3	/PROGRAMMER: C.MORRIN
		4	/VERSION 2.0
		5	/DATE OF LAST CHANGE: OCTOBER 31, 1977
		6	
		7	*****
		8	
		9	CSEG
		10	
		11	PUBLIC DISP,XMIT,HEXASC,HXASC1
		12	PUBLIC OUTPUT,DPROGM,DRSULT,FNASC
		13	EXTERN WAIT,EXIT,ASCHEX,ASCHX1
		14	EXTERN USRT,OPINFO,PRADD,FINAL
		15	EXTERN CUTOFF,ERROR,SAVE,START1
		16	EXTERN PRONT,STOPFG
		17	
		18	*****
		19	
		20	DSEG
		21	
0000	2046494E	22	ODATA1: DB 'FINAL='
0004	414C3D	23	ODATA2: DB 'DIFF='
0007	20444946	24	ODATA3: DB 'PRGM*AD='
0008	463D3D	25	ODATA4: DB 'CUTOFF='
000E	20505247	26	ODATA5: DB 'DISP*AD='
0012	4D2A4144		
0016	3D		
0017	2043544F		
001B	46463D		
001E	20444953		
0022	502A4144		
0026	3D		
0027	20235354		
002B	4550533D		
002F	2053544F		
0033	5020		
		28	ODATA7: DB 'STOP '
		29	
0007	30	LDATA1 EQU 7	
0007	31	LDATA2 EQU 7	
0009	32	LDATA3 EQU 9	
0007	33	L.DATA4 EQU 7	
0009	34	L.DATAS EQU 9	
0008	35	L.DATA6 EQU 8	
0006	36	L.DATA7 EQU 6	
		37	
		38	*****
		39	
		40	/DISPLAY PROGRAM ROUTINE:
		41	
		42	/INPUT INTERFACE:
		43	/DISPLAY MODE, REQUEST ADDRESS INFORMATION:
0035	211E00 D	44	DISP: LXI H,ODATAS
0038	0E09	45	MVI C,LDATAS

ISIS-II 8080/8085 MACRO ASSEMBLER, V4.0 OUTPUT PAGE 2

LOC	OBJ		LINE	SOURCE STATEMENT
003A	CDCF00	D	46	CALL OUTPUT ;' DISP*AD='
			47	;INITIALIZE PRADD:
003D	3EF1		48	MVI A,0F1H
003F	320100	E	49	STA PRADD+1
0042	214800	D	50	LXI H,DISP1 ;CALL DISP1 NEXT
0045	C30000	E	51	JMP EXIT
			52	
			53	;+++++ ;DISPLAY MODE, FIRST ADDRESS DIGIT
			54	;DISPLAY MODE, FIRST ADDRESS DIGIT
0048	FE2A		55	DISP1: CPI '*'
004A	CA5C00	D	56	JZ DISP2
004B	320100	E	57	STA OPINFO+1
0050	CD0000	E	58	CALL ASCHX1
0053	320000	E	59	STA PRADD
0056	217E00	D	60	LXI H,DISP3
0059	C30000	E	61	JMP EXIT
			62	
			63	;+++++ ;DISPLAY HARDWIRED MEMORY, CHANGE PRADD:
005C	CDBF00	D	65	DISP2: CALL XMIT
005F	216500	D	66	LXI H,DISP2A
0062	C30000	E	67	JMP EXIT
			68	
			69	;+++++ ;HARDWIRED MODE, 2ND ADDRESS DIGIT:
0065	CD0000	E	71	DISP2A: CALL ASCHEX
0068	07		72	RLC
0069	4F		73	MOV C,A
006A	0600		74	MVI B,0
006C	210000	E	75	LXI H,PROMT
006F	09		76	DAD B
			77	; (REG H) CONTAINS STARTING ADDRESS
			78	;GET STARTING ADDRESS:
0070	5E		79	MOV E,M
0071	23		80	INX
0072	56		81	MOV D,M
			82	;STORE STARTING ADDRESS IN PRADD:
0073	210000	E	83	LXI H,PRADD
0076	73		84	MOV M,E
0077	23		85	INX
0078	72		86	MOV M,D
0079	061F		87	MVI B,1FH
007B	C39A00	D	88	JMP D4
			89	
			90	;+++++ ;DISPLAY MODE, SECOND ADDRESS DIGIT
007E	320200	E	91	;DISPLAY MODE, SECOND ADDRESS DIGIT
0081	CD0000	E	92	DISP3: STA OPINFO+2
0084	210000	E	93	CALL ASCHEX
0087	B6		94	LXI H,PRADD
0088	77		95	ORA M
			96	MOV M,A ;PRADD NOW CONTAINS
			97	;ADDRESS OF FIRST PROGRAM STEP TO BE DISPLAYED
0089	212700	D	98	LXI H,ODATA6
00BC	0E08		99	MVI C,LDATA6
008E	CDCF00	D	100	CALL OUTPUT ;' *STEPS='

LOC	OBJ		LINE	SOURCE STATEMENT
0091	219700	D	101	LXI H,DISP4
0094	C30000	E	102	JMP EXIT
			103	
			104	;+++++ ;DISPLAY MODE, NUMBER OF STEPS
			105	;DPROGM (OUTPUT MODULE) IS MAIN ROUTINE
			106	;FOR DISPLAY MODE. IT REQUIRES ADDRESS
			107	;IN PRADD.
0097	CB0000	E	109	DISP4: CALL ASCHEX
009A	47		110	D4: MOV B,A
009B	CDEC00	D	111	CALL DPROGM
009E	C5		112	PUSH B
009F	01204E		113	LXI B,20000
00A2	CD0000	E	114	CALL WAIT ;DISPLAY 1 SEC
00A5	C1		115	POP B
00A6	2A0000	E	116	LHLD PRADD
00A9	110400		117	LXI D,4
00AC	19		118	DAD D
00AD	220000	E	119	SHLD PRADD
00B0	3A0000	E	120	LDA STOPFG
00B3	E6FF		121	ANI OFFH ;SET FLAGS
00B5	C20000	E	122	JNZ START1
			123	; "STOP" FUNCTION HAS BEEN DISPLAYED
00B8	05		124	DCR B
00B9	C29B00	D	125	JNZ DISP4+4
00BC	C30000	E	126	JMP START1
			127	
			128	;*****
			129	
			130	;TRANSMIT CHARACTER ROUTINE:
			131	;CHARACTER MUST BE IN ACC
			132	
00BF	C5		133	XMIT: PUSH B
00C0	47		134	MOV B,A
00C1	3A0100	E	135	XMIT1: LDA USRT+1 ;GET USRT STATUS
00C4	E601		136	ANI 1 ;GET TXRDY BIT
00C6	CAC100	D	137	JZ XMIT1 ;READY?
00C9	78		138	MOV A,B ;YES
00CA	320000	E	139	STA USRT
00CD	C1		140	POP B
00CE	C9		141	RET
			142	
			143	;*****
			144	
			145	;OUTPUT ROUTINE
			146	
			147	;THIS ROUTINE OUTPUTS A BLOCK OF DATA
			148	;TO A 8251 USRT.
			149	;OUTPUT REQUIRES THE FOLLOWING:
			150	;REG HL MUST CONTAIN BEGINNING ADDRESS OF DATA.
			151	;REG C MUST CONTAIN LENGTH OF DATA BLOCK.
			152	;DATA MUST BE IN ASCII FORMAT.
			153	
00CF	F5		154	OUTPUT: PUSH PSW
00D0	7E		155	MOV A,M ;GET NEXT CHARACTER

LOC	OBJ	LINE	SOURCE STATEMENT
00D1	CDBF00	D 156	CALL XMIT ;TRANSMIT IT
00D4	23	157	INX H
00D5	0D	158	; DCR C
00D6	C2D000	D 159	JNZ OUTPUT+1 ;MORE CHARACTERS?
00D9	F1	160	POP PSW
00DA	C9	161	RET
		162	
		163	*****
		164	
		165	;HEXADECIMAL TO ASCII CONVERSION ROUTINES:
		166	;ALL ROUTINES START AND END WITH DATA IN ACC
		167	;HEXASC = HEX TO ASCII (HEX: LOWER HALF ACC)
		168	;HXASC1 = HEX TO ASCII (HEX: UPPER HALF ACC)
		169	
00DB	0F	170	HXASC1: RRC
00DC	0F	171	RRC
00DD	0F	172	RRC
00DE	0F	173	RRC
00DF	E60F	174	HEXASC: ANI 0FH
00E1	FE0A	175	CPI 10
00E3	D2E900	D 176	JNC HEX1
00E6	F630	177	ORI 30H
00EB	C9	178	RET
00E9	C637	179	HEX1: ADI 37H
00EB	C9	180	RET
		181	
		182	*****
		183	
		184	;DISPLAY PROGRAM STEP ROUTINE
		185	
		186	;THIS PROGRAM USES THE PROGRAM POINTER PRADD
		187	;AS AN INPUT. THE OUTPUT IS THE CONTENTS OF
		188	;PRADD, AND THE CONTENTS OF THE INSTRUCTION
		189	;POINTED TO BY PRADD.
		190	
		191	;THE FORMAT OF THE OUTPUT IS:
		192	; 'PROG#AD=XX'
		193	; 'FN-DATA-DB'
		194	;WHERE XX = CONTENTS OF PRADD
		195	; FN = FUNCTION = (PRADD)
		196	; DATA = POSITION = (PRADD+1,+2)
		197	; DB = DEADBAND = (PRADD+3)
		198	
00EC	F5	199	DPROGM: PUSH PSW
00ED	C5	200	PUSH B
00EE	D5	201	PUSH D
00EF	E5	202	PUSH H
		203	;GET PRADD, CONVERT TO ASCII,
		204	;AND STORE IN OPINFO+1,+2.
00F0	2A0000	E 205	LHLD PRADD
00F3	7D	206	MOV A,L
00F4	CDBF00	D 207	CALL HXASC1
00F7	320100	E 208	STA OPINFO+1
00FA	7D	209	MOV A,L
00FB	CDBF00	D 210	CALL HEXASC
			;OPINFO+1,+2 CON

LOC	OBJ	LINE	SOURCE STATEMENT		
			TAINS		
00FE 320200	E	211	STA	OPINFO+2	;PROGRAM ADDRESS
		212	GET FUNCTION, CONVERT TO ASCII,		
		213	;AND STORE IN OPINFO+4,+5.		
0101 7E		214	MOV	A,M	
0102 FEFO		215	CPI	OFOH	
0104 D23C01	D	216	JNC	STOP	
0107 CDC101	D	217	CALL	FNASC	;CONVERT FUNCTION TO ASC
		II			
		218	FNASC WILL STORE ASCII DATA IN OPINFO+4,+5		
		219			
		220	RESET "STOP FUNCTION" FLAG		
010A 3E00		221	MVI	A,0	
010C 320000	E	222	STA	STOPFG	
		223			
		224	;GET DATA, CONVERT TO ASCII, AND		
		225	;STORE IN OPINFO+7,+8,+9,+10.		
010F 23		226	INX	H	
0110 56		227	MOV	D,M	
0111 23		228	INX	H	
0112 5E		229	MOV	E,M	
0113 EB		230	XCHG		;HL = DATA
0114 CD0000	E	231	CALL	SAVE	
0117 EB		232	DATA STORED IN OPINFO+7 TO OPINFO+10		
		233	XCHG		;HL = (PRADD)+2
		234	;GET DEADBAND, CONVERT TO ASCII,		
		235	;AND STORE IN OPINFO+12,+13.		
0118 23		236	INX	H	
0119 7E		237	MOV	A,M	
011A CDD800	D	238	CALL	HXASC1	
011B 320C00	E	239	STA	OPINFO+12	
0120 7E		240	MOV	A,M	
0121 CDDFO0	D	241	CALL	HEXASC	;OPINFO+12,+13 C
		ONTAINS			
0124 320D00	E	242	STA	OPINFO+13	;DEADBAND DATA
		243	;OUTPUT 'PRGM#AD=XX FN-DATA-DB',		
0127 210E00	D	244	LXI	H,ODATA3	
012A 0E09		245	MVI	C,LDATA3	
012C CDCF00	D	246	CALL	OUTPUT ;' PRGM#AD='	
012F 210100	E	247	LXI	H,OPINFO+1	
0132 0E0D		248	MVI	C,13	
0134 CDCF00	D	249	CALL	OUTPUT ;(PRGM#AD=)XX FF-XXXX-X	
		X			
0137 E1		250	DP1:	POP	H
0138 D1		251	POP	D	
0139 C1		252	POP	B	
013A F1		253	POP	PSW	
013B C9		254	RET		
		255			
		256	+++++		
		257	;DISPLAY PROGRAM STEP, FUNCTION="STOP"		
013C 3EFF		258	STOP:	MVI	A,OFFH
013E 320000	E	259	STA	STOPFG	
0141 210E00	D	260	LXI	H,ODATA3	
0144 0E09		261	MVI	C,LDATA3	

LOC	OBJ	LINE	SOURCE STATEMENT
0146	CDCF00	D 262	CALL OUTPUT
0149	3A0100	E 263	LDA OPINFO+1
014C	CDBF00	D 264	CALL XMIT
014F	3A0200	E 265	LDA OPINFO+2
0152	CDBF00	D 266	CALL XMIT
0155	212F00	D 267	LXI H,ODATA7
0158	OE06	268	MVI C,LDATA7
015A	CDCF00	D 269	CALL OUTPUT ;' STOP '
015D	C33701	D 270	JMP DP1
		271	
		272	;*****
		273	
		274	;DRSULT CALCULATES THE ABSOLUTE VALUE OF
		275	;THE ERROR (DESIRED POSITION - FINAL POSITION),
		276	;AND DISPLAYS BOTH THE FINAL POSITION
		277	;AND THE ERROR.
		278	
0160	F5	279 DRSULT: PUSH PSW	
0161	C5	280 PUSH B	
0162	E5	281 PUSH H	
		282	
		283	;DISPLAY CUTOFF POSITION:
0163	2A0000	E 284 LHLD CUTOFF	
0166	CD0000	E 285 CALL SAVE	
0169	211700	D 286 LXI H,ODATA4	
016C	OE07	287 MVI C,LDATA4	
016E	CDCF00	D 288 CALL OUTPUT ;' CTOFF='	
0171	210700	E 289 LXI H,OPINFO+7	
0174	OE04	290 MVI C,4	
0176	CDCF00	D 291 CALL OUTPUT	
		292	
		293	;DISPLAY FINAL POSITION:
0179	2A0000	E 294 LHLD FINAL	
017C	CD0000	E 295 CALL SAVE	
		296	;SAVE CONVERTS FINAL POSITION TO ASCII AND
		297	;SAVES IN OPINFO+7 TO OPINFO+10
017F	210000	D 298 LXI H,ODATA1	
0182	OE07	299 MVI C,LDATA1	
0184	CDCF00	D 300 CALL OUTPUT ;' FINAL='	
0187	210700	E 301 LXI H,OPINFO+7	
018A	OE04	302 MVI C,4	
018C	CDCF00	D 303 CALL OUTPUT ;(FINAL=) 'XXXX'	
		304	
		305	;CALCULATE DIFFERENCE:
018F	2A0000	E 306 LHLD PRADD	
0192	23	307 INX H	
(93	46	308 MOV B,M	
4 23		309 INX H	
0195	4E	310 MOV C,M	
		311	;GET A/D DATA:
0196	2A0000	E 312 LHLD FINAL ;HL = A/D DATA	
		313	;SUBTRACT:
0197	79	314 MOV A,C	
019A	95	315 SUB L	
019B	6F	316 MOV L,A	

LOC	OBJ	LINE	SOURCE STATEMENT	
019C	78	317	MOV	A,B
019D	9C	318	SBB	H
019E	67	319	MOV	H,A
		320	;DIFFERENCE IS IN REG HL,	
		321	;CALCULATE ABSOLUTE VALUE.	
019F	D2AA01	D	JNC	D1 ;IF NO BORROW, THEN OK
01A2	3E00	322	MVI	A,0
01A4	95	323	SUB	L
01A5	6F	324	MOV	L,A
01A6	3E00	325	MVI	A,0
01A8	9C	326	MVI	A,0
01A9	67	327	SBB	H
		328	MOV	H,A
		329		
		330	;OUTPUT DIFFERENCE DATA:	
01AA	CD0000	E	331	D1: CALL SAVE
01AD	210700	D	332	LXI H,0DATA2
01B0	0E07	333	MVI C	L,DATA2
01B2	CDCFO0	D	334	CALL OUTPUT ;' DIFF=='
01B5	210700	E	335	LXI H,OPINFO+7
01B8	0E04	336	MVI C	,4
01BA	CDCFO0	D	337	CALL OUTPUT ;(DIFF==)' XXXX'
01BD	E1	338	POP	H
01BE	C1	339	POP	B
01BF	F1	340	POP	PSW
01C0	C9	341	RET	
		342		
		343	*****	
		344		
		345	;FNASC CONVERTS FUNCTION(PASSED IN ACC) TO ASCII	
		346	;ASCII DATA IS STORED IN OPINFO+4,+5 BY FNASC	
		347		
01C1	F5	348	FNASC:	PUSH PSW
01C2	C5	349	PUSH	B
01C3	E60F	350	ANI	OFH
01C5	CAF701	D	351	JZ SU ;SU = 0
01C8	3D	352	DCR	A
01C9	CAFD01	D	353	JZ SL
01CC	3D	354	DCR	A
01CD	CA0302	D	355	JZ EU
01D0	3D	356	DCR	A
01D1	CA0902	D	357	JZ EE
01D4	3D	358	DCR	A
01D5	CA0F02	D	359	JZ WU
01D8	3D	360	DCR	A
01D9	CA1502	D	361	JZ WL ;WL = 5
01DC	3D	362	DCR	A
01DD	CA1B02	D	363	JZ WR
01E0	3D	364	DCR	A
01E1	3D	365	DCR	A
01E2	CA2102	D	366	JZ HO ;HO = 8
01E3	3D	367	DCR	A
01E6	CA2702	D	368	JZ HC ;HC = 9
01E9	013F3F	369	LXI	B,'??'
01EC	78	370	RET1:	MOV A,B
01ED	320400	E	371	STA OPINFO+4

LOC	OBJ	LINE	SOURCE STATEMENT	
01F0	79	372	MOV	A,C
01F1	320500	E 373	STA	OPINFO+5
01F4	C1	374	POP	B
01F5	F1	375	POP	PSW
01F6	C9	376	RET	
01F7	015553	377 SU:	LXI	B,'SU'
01FA	C3EC01	D 378	JMP	RET1
01FD	014C53	379 SL:	LXI	B,'SL'
0200	C3EC01	D 380	JMP	RET1
0203	015545	381 EU:	LXI	B,'EU'
0206	C3EC01	D 382	JMP	RET1
0209	014545	383 EE:	LXI	B,'EE'
020C	C3EC01	D 384	JMP	RET1
020F	015557	385 WU:	LXI	B,'WU'
0212	C3EC01	D 386	JMP	RET1
0215	014C57	387 WL:	LXI	B,'WL'
0218	C3EC01	D 388	JMP	RET1
021B	015257	389 WR:	LXI	B,'WR'
021E	C3EC01	D 390	JMP	RET1
0221	014F48	391 HO:	LXI	B,'HO'
0224	C3EC01	D 392	JMP	RET1
0227	014348	393 HC:	LXI	B,'HC'
022A	C3EC01	D 394	JMP	RET1
		395		
		396	END	

PUBLIC SYMBOLS

DISP	D 0035	DPROGM D 00EC	DRSULT D 0160	FNASC D 01C1
HEXASC	D 00DF	HXASC1 D 00DB	OUTPUT D 00CF	XMIT D 00BF

EXTERNAL SYMBOLS

ASCHEX	E 0000	ASCHX1 E 0000	CUTOFF E 0000	ERROR E 0000
EXIT	E 0000	FINAL E 0000	OPINFO E 0000	PRADD E 0000
PROMT	E 0000	SAVE E 0000	START1 E 0000	STOPFG E 0000
USRT	E 0000	WAIT E 0000		

USER SYMBOLS

ASCHEX	E 0000	ASCHX1 E 0000	CUTOFF E 0000	D1 D 01AA
D4	D 009A	DISP D 0035	DISP1 D 0048	DISP2 D 005C
DISP2A	D 0065	DISP3 D 007E	DISP4 D 0097	DP1 D 0137
DPROGM	D 00EC	DRSULT D 0160	EE D 0209	ERROR E 0000
EU	D 0203	EXIT E 0000	FINAL E 0000	FNASC D 01C1
HC	D 0227	HEX1 D 00E9	HEXASC D 00DF	HO D 0221
HXASC1	D 00DB	LDATA1 A 0007	LDATA2 A 0007	LDATA3 A 0009
LDATA4	A 0007	LDATA5 A 0009	LDATA6 A 0008	LDATA7 A 0006
ODATA1	D 0000	ODATA2 D 0007	ODATA3 D 000E	ODATA4 D 0017
ODATA5	D 001E	ODATA6 D 0027	ODATA7 D 002F	OPINFO E 0000
OUTPUT	D 00CF	PRADD E 0000	PROMT E 0000	RET1 D 01EC
SAVE	E 0000	SL D 01FD	START1 E 0000	STOP D 013C
STOPFG	E 0000	SU D 01F7	USRT E 0000	WAIT E 0000
WL	D 0215	WR D 021B	WU D 020F	XMIT D 00BF
XMIT1	D 00C1			

ASSEMBLY COMPLETE, NO ERRORS

ISIS-II ASSEMBLER SYMBOL CROSS REFERENCE, V2.1

PAGE 1

ASCHEX	13	71	93	109					
ASCHX1	13	58							
CUTOFF	15	284							
D1	322	331*							
D4	88	110*							
DISP	11	44*							
DISP1	50	55*							
DISP2	56	65*							
DISP2A	66	71*							
DISP3	60	92*							
DISP4	101	109*	125						
DP1	250*	270							
DPROGM	12	111	199*						
DRSULT	12	279*							
EE	357	383*							
ERROR	15								
EU	355	381*							
EXIT	13	51	61	67	102				
FINAL	14	294	312						
FNASC	12	217	348*						
HC	368	393*							
HEX1	176	179*							
HEXASC	11	174*	210	241					
HO	366	391*							
HXASC1	11	170*	207	238					
LDATA1	30*	299							
LDATA2	31*	333							
LDATA3	32*	245	261						
LDATA4	33*	287							
LDATA5	34*	45							
LDATA6	35*	99							
LDATA7	36*	268							
ODATA1	22*	298							
ODATA2	23*	332							
ODATA3	24*	244	260						
ODATA4	25*	286							
ODATA5	26*	44							
ODATA6	27*	98							
ODATA7	28*	267							
OPINFO	14	57	92	208	211	239	242	247	263
	265	289	301	335	371	373			
OUTPUT	1	12	46	100	154*	159	246	249	262
	269	288	291	300	303	334	337		
PRAADD	14	49	59	83	94	116	119	205	306
PROMT	16	75							
RETI	370*	378	380	382	384	386	388	390	392
	394								
SAVE	15	231	285	295	331				
SL	353	379*							
START1	15	122	126						
STOP	216	258*							
STOPFG	16	120	222	259					
SU	351	377*							
USR1	14	135	139						
WAIT	13	114							
WL	361	387*							
WR	363	389*							

ISIS-II ASSEMBLER SYMBOL CROSS REFERENCE, V2.1

PAGE 2

NU	359	385*				
XMIT	11	65	133*	156	264	266
XMIT1	135*	137				

CROSS REFERENCE COMPLETE

ISIS-II 8080/8085 MACRO ASSEMBLER, V4.0

PROGW PAGE 1

LOC	OBJ	LINE	SOURCE STATEMENT
		1	NAME PROGW
		2	;PROGRAMMER: C.MORRIN
		4	;VERSION 2.0W
		5	;DATE OF LAST CHANGE: NOVEMBER 3, 1977
		6	
		7	;*****
		8	
		9	CSEG
		10	
		11	PUBLIC PROGR,PRG11B
		12	;PROGXX ADDRESSES ARE ALSO ENTRY POINTS
		13	EXTRN PRADD,OUTPUT,WAIT
		14	EXTRN TRANSO
		15	EXTRN STATE,EXIT,ERROR,OPINFO
		16	EXTRN START1,DPROGM,GETPOT,XMIT
		17	EXTRN ASCHEX,ASCHX1,HEXASC,HXASC1
		18	
		19	;*****
		20	
		21	;OUTPUT MESSAGE TABLE:
		22	DSEG
		23	
0000	20505247	24	OPRG1: DB ' PRGM*AD='
0004	4D2A4144		
0008	3D		
0009	20532C45	25	OPRG2: DB ' S,E,W,H, T, OR N?'
000D	2C572C48		
0011	2C20542C		
0015	204F5220		
0019	4E3F		
001B	20444541	26	OPRG3: DB ' DEADBND='
001F	44424E44		
0023	3D		
0024	20444154	27	OPRG4: DB ' DATA='
0028	413D		
002A	204F5045	28	OPRG5: DB ' OPEN OR CLOSE?'
002E	4E204F52		
0032	20434C4F		
0036	53453F		
0039	2055204F	29	OPRG6: DB ' U OR L?'
003D	52204C3F		
0041	20454E44	30	OPRG7: DB ' END OF PROGRAM?'
0045	204F4620		
0049	50524F47		
004D	52414D		
0050	2053204F	31	OPRG8: DB ' U OR E?'
0054	5220453F		
		32	
0009	33	LPRG1 EQU 9	
0012	34	LPRG2 EQU 18	
0009	35	LPRG3 EQU 9	
0006	36	LPRG4 EQU 6	
000F	37	LPRG5 EQU 15	

LOC	OBJ	LINE	SOURCE STATEMENT
		38	LPRG6 EQU 8
000F		39	LPRG7 EQU 15
0008		40	LPRG8 EQU 8
		41	
		42	;*****
		43	
		44	;PROGRAM ROUTINE:
		45	
		46	;THIS ROUTINE PROVIDES THE BULK OF THE HAND
		47	;CONTROLLER INTERFACE REQUIRED TO PROGRAM
		48	;THE PROGRAMMER. THE PROGRAMMER
		49	;ACCEPTS AND OPERATES ON ONE CHARACTER AT A
		50	;TIME. A FINITE STATE STRUCTURE IS USED TO
		51	;DETERMINE THE INTERPRETATION OF THE
		52	;INCOMING DATA.
		53	
		54	CSEG
		55	
		56	;+++++
		57	;PROGRAM MODE, REQUEST ADDRESS INFORMATION
0000	210000	D	58 PROGR: LXI H,OPRG1 ;'PROGRAM ADDRESS='
0003	0E09		59 MVI C,LPRG1
0005	CD0000	E	60 CALL OUTPUT
0008	210E00	C	61 LXI H,PRG2
0008	C30000	E	62 JMP EXIT
		63	
		64	
		65	;+++++
		66	;PROGRAM MODE, FIRST ADDRESS DIGIT
000E	320100	E	67 PROG2: STA OPINFO+1 ;ADDRESS BYTE, HIGH
0011	CD0000	E	68 CALL ASCHX1
0014	320000	E	69 STA PRADD
0017	211000	C	70 LXI H,PRG3 ;CALL PROG3 NEXT
001A	C30000	E	71 JMP EXIT
		72	
		73	;+++++
		74	;PROGRAM MODE, SECOND ADDRESS DIGIT.
		75	;REQUEST FUNCTION CHARACTER
001B	320200	E	76 PROG3: STA OPINFO+2 ;ADDRESS BYTE, LOW
0020	CD0000	E	77 CALL ASCHEX
0023	210000	E	78 LXI H,PRADD
0026	B6		79 ORA M
0027	77		80 MOV M,A
		81	;STORE 2 HEX DIGITS IN PRADD
0028	01204E		82 LXI B,20000D
		83	;WAIT 1 SECOND = 2000 X 50 MICROSECONDS
002B	CD0000	E	84 CALL WAIT
		85	
		86	;+++++
		87	; THIS IS THE STARTING POINT AFTER A STEP HAS
		88	;ALREADY BEEN PROGRAMMED.
002E	210900	D	89 PROG3Y: LXI H,OPRG2
0031	0E12		90 MVI C,LPRG2
0033	CD0000	E	91 CALL OUTPUT ;' SU,SL,E,W, T, OR N?'
0036	213C00	C	92 LXI H,PRG4 ;CALL PROG4 NEXT

LOC	OBJ	LINE	SOURCE STATEMENT	
0039	C30000	E 93	JMP	EXIT
		94		
		95	;+++++ ;PROGRAM MODE, INPUT FIRST FUNCTION CHARACTER.	
		96	;SHOULDER GROUP, ELBOW GROUP, OR WRIST GROUP?	
		97	;EXTEND IS PART OF ELBOW GROUP).	
		98		
003C	FE4E	CPI 'N'		
003E	CAA700	C 100	JZ	PROG4N
0041	FE54	101	CPI	'T'
0043	CA0000	E 102	JZ	TRANS0
0046	320400	E 103	STA	OPINFO+4
0049	FE48	104	CPI	'H'
004B	CA6000	C 105	JZ	PROG4H
004E	FE53	106	CPI	'S'
0050	CA7000	C 107	JZ	PROG4S
0053	FE45	108	CPI	'E'
0055	CA8000	C 109	JZ	PROG4E
0058	FE57	110	CPI	'W'
005A	CA9000	C 111	JZ	PROG4W
005D	C30000	E 112	JMP	ERROR
		113		
		114	;HAND OPEN = 1000 BINARY	
		115	;HAND CLOSE = 1001 BINARY	
0060	CD0000	E 116	PROG4H: CALL	XMIT
0063	212A00	D 117	LXI	H,OPRG5
0066	0E0F	118	MVI	C,LPRG5
0068	CD0000	E 119	CALL	OUTPUT ;'OPEN OR CLOSE?'
006B	3E08	120	MVI	A,B
006D	C39D00	C 121	JMP	END4
		122		
0070	CD0000	E 123	PROG4S: CALL	XMIT
0073	213900	D 124	LXI	H,OPRG6
0076	0E08	125	MVI	C,LPRG6
0078	CD0000	E 126	CALL	OUTPUT
007B	3E00	127	MVI	A,O
		128	;SHOULDER UP/DN = 000 BINARY	
		129	;SHOULDER LF/RT = 001 BINARY	
007D	C39D00	C 130	JMP	END4
		131		
0080	CD0000	E 132	PROG4E: CALL	XMIT
		133	;ELBOW UP/DN = 010 BINARY	
		134	;ELBOW EXTEND = 011 BINARY	
0083	215000	D 135	LXI	H,OPRG8
0086	0E08	136	MVI	C,LPRG8
0088	CD0000	E 137	CALL	OUTPUT ;'UP/DOWN=U EXTEND=E
008B	3E02	138	MVI	A,2
008D	C39D00	C 139	JMP	END4
		140		
0090	CD0000	E 141	PROG4W: CALL	XMIT
		142	;WRIST UP/DN = 100 BINARY	
		143	;WRIST LF/RT = 101 BINARY	
0093	213900	D 144	LXI	H,OPRG6
0096	0E08	145	MVI	C,LPRG6
0098	CD0000	E 146	CALL	OUTPUT ;' UP/DOWN=U LEFT/RT=L'
009B	3E04	147	MVI	A,4

LOC	OBJ	LINE	SOURCE STATEMENT	
007D	2A0000	E 148	END4:	LHLD PRADD
00A0	77	149	MOV	M,A
00A1	21BD00	C 150	LXI	H,PROG5
00A4	C30000	E 151	JMP	EXIT
		152		
		153	;END OF PROGRAM MODE. INSERT STOP	
		154	;FLAG AT END OF PROGRAM.	
00A7	214100	D 155	PROG4N: LXI	H,OPRG7
00AA	0EOF	156	MVI	C,LPRG7
00AC	CD0000	E 157	CALL	OUTPUT
00AF	011027	158	LXI	B,10000
00B2	CD0000	E 159	CALL	WAIT ;WAIT .5 SEC
00B5	2A0000	E 160	LHLD	PRADD
00BB	36FF	161	MVI	M,OFFH
		162	;SET STOP FLAG IN PROGRAM	
00BA	C30000	E 163	JMP	START1
		164		
		165	+++++PROGRAM MODE, SECOND FUNCTION CHARACTER	
00BD	320500	E 167	PROG5: STA	OPINFO+5
00C0	FE55	168	CPI	'U'
00C2	CAE000	C 169	JZ	UP
00C5	2A0000	E 170	LHLD	PRADD
00C8	FE45	171	CPI	'E'
00CA	CAFE00	C 172	JZ	EXTEND
00CD	FE4C	173	CPI	'L'
00CF	CADF00	C 174	JZ	LEFT
00D2	FE4F	175	CPI	'O'
00D4	CA0601	C 176	JZ	OPEN
00D7	FE43	177	CPI	'S'
00D9	CA0501	C 178	JZ	CLOSE
00DC	C30000	E 179	JMP	ERROR
		180		
00DF	34	181	LEFT:	INR M
00E0	210000	D 182	UP:	LXI H,OPRG1
00E3	0EOF	183	MVI	C,LPRG1
00E5	CD0000	E 184	CALL	OUTPUT '' PROG*AD='
00EB	210100	E 185	LXI	H,OPINFO4
00EB	0EOF5	186	MVI	C,S
00ED	CD0000	E 187	CALL	OUTPUT ;OUTPUT 'AA FF'
00F0	212400	D 188	LXI	H,OPRG4
00F3	0EOF6	189	MVI	C,LPRG4
00F5	CD0000	E 190	CALL	OUTPUT '' DATA='
		191	;DISPLAY NOW READS 'PROG*AD=AA'	
		192		'FF DATA='
00FB	212601	C 193	LXI	H,PROG6
00FB	C30000	E 194	JMP	EXIT
		195		
00FE	7E	196	EXTEND: MOV	A,M ;CORRECT FUNCT
00FF	F603	197	ORI	3
0101	77	198	MOV	M,A
0102	C3E000	C 199	JMP	UP
		200	;OUTPUT 'AA FF', UPDATE STATE AND EXIT	
		201		
0105	34	202	CLOSE: INR	M

AD-A119 327

NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA
WORK SYSTEMS PACKAGE AUTOMATIC TOOL INTERCHANGE. LABORATORY STU--ETC(U)
JUN 82 C E MORRIN
NOSC/TR-262

F/G 13/10

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NL

2 hr 2

AD A
9327

END
DATE
FILED
[REDACTED]-82
DTIC

LOC	OBJ	LINE	SOURCE STATEMENT	
0106	23	203	OPEN:	INX H
0107	3600	204	MVI	M,0
0109	23	205	INX	H
010A	3600	206	MVI	M,0
010C	23	207	INX	H
010D	3600	208	MVI	M,0
010F	3E30	209	MVI	A,'0'
0111	320700	E 210	STA	OPINFO+7
0114	320800	E 211	STA	OPINFO+8
0117	320900	E 212	STA	OPINFO+9
011A	320A00	E 213	STA	OPINFO+10
011D	320C00	E 214	STA	OPINFO+12
0120	320D00	E 215	STA	OPINFO+13
0123	C3EB01	C 216	JMP	PRG11A
		217	;NOTE: REG HL=(PRADD)+3 AS REQUIRED	
		218		
		219	+++++	
		220	;PROGRAM MODE, FIRST DATA DIGIT	
0126	FE2A	221	PROG6:	CPI '*'
0128	CA4E01	C 222	JZ	PROG6A ;AUTO DATA READ
012B	320700	E 223	STA	OPINFO+7 ;FIRST DATA BYTE, HIGH
012E	CD0000	E 224	CALL	ASCHX1
0131	2A0000	E 225	LHLD	PRADD
0134	23	226	INX	H
		227	;REG HL HAS PROGRAM ADDRESS FOR FIRST DATA BYTE	
0135	77	228	MOV	M,A
		229	;STORE FIRST HALF OF FIRST DATA BYTE	
0136	213C01	C 230	LXI	H,PROG7 ;CALL PROG7 NEXT
0139	C30000	E 231	JMP	EXIT
		232	+++++	
		233	+++++	
		234	;PROGRAM MODE, SECOND DATA DIGIT	
013C	320800	E 235	PROG7:	STA OPINFO+8 ;FIRST DATA BYTE, LOW
013F	CD0000	E 236	CALL	ASCHEX
0142	2A0000	E 237	LHLD	PRADD
0145	23	238	INX	H
		239	;H = PROGRAM ADDRESS OF FIRST BYTE	
0146	B6	240	ORA	M ;COMBINE BOTH DATA HALVES
0147	77	241	MOV	M,A ;STORE FIRST DATA BYTE
0148	218501	C 242	LXI	H,PROG8
014B	C30000	E 243	JMP	EXIT
		244	+++++	
		245	+++++	
		246	;AUTOMATIC DATA READ	
014E	CD0000	E 247	PROG6A:	CALL GETPOT
		248	;DATA WILL BE STORED IN PRADD+1,+2,OPINFO+8-11	
		249	;NEED TO SET APPROPRIATE DEADBAND:	
0151	2A0000	E 250	LHLD	PRADD
0154	7E	251	MOV	A,M ;GET FUNCTION
0155	FE00	252	CPI	0
0157	CA7601	C 253	JZ	XSU
015A	FE01	254	CPI	1
015C	CA7B01	C 255	JZ	XSL
015F	FE02	256	CPI	2
0161	CA7B01	C 257	JZ	XSL ;EU

LOC	OBJ	LINE	SOURCE STATEMENT		
0164	FE03	258	CPI	3	
0166	CA7601	C 259	JZ	XSU	;EE
0169	FE04	260	CPI	4	
016B	CA7601	C 261	JZ	XSU	;HU
016E	FE05	262	CPI	5	
0170	CA7B01	C 263	JZ	XSL	;WL
0173	C30000	E 264	JMP	START1	
0176	3E03	265	XSU:	MVI	A,3
0178	C37D01	C 266	JMP	XX	
017B	3E05	267	XSL:	MVI	A,5
017D	110300	268	XX:	LXI	D,3
0180	19	269	DAD	D	;HL = (PRADD)+3
0181	77	270	MOV	M,A	;STORE DEADBAND
0182	C3EB01	C 271	JMP	PRG1A	
		272			
		273	;+++++PROGRAM MODE, THIRD DATA DIGIT		
0185	320900	E 274	PROG9:	STA	OPINFO+9 ;SECOND DATA BYTE, HIGH
0188	CD0000	E 275	CALL	ASCHX1	
018B	2A0000	E 276	LHLD	PRADD	
018E	23	277	INX	H	
018F	23	278	INX	H	
0190	77	279	INX	H	
0191	219701	C 280	MOV	M,A	
0194	C30000	E 281	LXI	H,PROG9	
		282	JMP	EXIT	
		283			
		284	;+++++PROGRAM MODE, FOURTH DATA DIGIT		
0197	320A00	E 285	PROG9:	STA	OPINFO+10 ;SECOND DATA BYTE, LOW
019A	CD0000	E 286	CALL	ASCHEX	
019D	2A0000	E 287	LHLD	PRADD	
01A0	23	288	INX	H	
01A1	23	289	INX	H	
01A2	B6	290	ORA	M	
01A3	77	291	MOV	M,A	
		292			
		293	;STORE SECOND DATA BYTE IN PROGRAM		
01A4	210000	D 294	LXI	H,OPRG1	
01A7	OE09	295	MVI	C,LPRG1	
01A9	CD0000	E 296	CALL	OUTPUT	'; PROG#AD='
01AC	210100	E 297	LXI	H,OPINFO+1	
01AF	OE0A	298	MVI	C,10	
01B1	CD0000	E 299	CALL	OUTPUT	';AA FF-DDDD'
		300	;DISPLAY NOW READS 'PROG#AD=AA'		
		301			'FF-DDDD'
01B4	011027	302	LXI	B,10000	
01B7	CD0000	E 303	CALL	WAIT	;WAIT .5 SECOND
01BA	211B00	D 304	LXI	H,OPRG3	
01BD	OE09	305	MVI	C,LPRG3	
01BF	CD0000	E 306	CALL	OUTPUT	';DEADBAND='
01C2	21C801	C 307	LXI	H,PROG10	
01C5	C30000	E 308	JMP	EXIT	
		309			
		310	;+++++PROGRAM MODE, FIRST DEADBAND DIGIT		
01C8	320C00	E 311	PROG10:	STA	OPINFO+12 ;DEADBAND BYTE, HIGH

LOC	OBJ	LINE	SOURCE STATEMENT
01CB	CD0000	E 313	CALL ASCHX1
01CE	2A0000	E 314	LHLD PRADD
01D1	110300	315	LXI D,3
01D4	19	316	DAD D ;HL = (PRADD)+3
01D5	77	317	MOV M,A
		318	;STORE FIRST HALF OF DEADBAND DATA IN PRADD
01D6	21DC01	C 319	LXI H,PROG11
01D9	C30000	E 320	JMP EXIT
		321	
		322	;+++++ ;PROGRAM MODE, SECOND DEADBAND DIGIT
01DC	320000	E 323	PROG11: STA OPINFO+13 ;DEADBAND BYTE, LOW
01DF	CD0000	E 324	CALL ASCHEX
01E2	2A0000	E 325	LHLD PRADD
01E5	110300	326	LXI D,3
01E8	19	327	DAD D ;HL = (PRADD)+3
01E9	B6	328	ORA M
01EA	77	329	MOV M,A
		330	
		331	
		332	;+++++ ;DISPLAY COMPLETED PROGRAM STEP AND GET
		333	;READY TO PROGRAM ANOTHER.
		334	;NOTE: REG HL = (PRADD)+3 FOR ENTRY HERE
01EB	CD0000	E 335	PRG11A: CALL DPRGM
		336	;DISPLAY IS NOW: 'PROG*AD=AA'
		337	'FF-DDDD-DB'
		338	;
		339	;UPDATE PRADD:
01EE	23	340	INX H ;HL=(PRADD)+4
01EF	220000	E 341	SHLD PRADD
		342	
		343	;+++++ ;EXTERNAL ENTRY POINT (RETURN FROM TRANSFER)
		344	;GET READY TO PROGRAM ANOTHER STEP:
01F2	3A0000	E 345	PRG11B: LDA PRADD
01F5	CD0000	E 346	CALL HXASC1
01F8	320100	E 347	STA OPINFO+1
		348	;STORE FIRST DIGIT OF ADDRESS
01FB	3A0000	E 349	LDA PRADD
01FE	CD0000	E 350	CALL HEXASC
0201	320200	E 351	STA OPINFO+2
		352	;STORE 2ND DIGIT OF ADDRESS
0204	210000	D 353	LXI H,OPRG1
0207	0E09	354	MVI C,LPRG1
0209	CD0000	E 355	CALL OUTPUT ;'PROGRAM ADDRESS='
020C	210100	E 356	LXI H,OPINFO+1
020F	0E02	357	MVI C,2
0211	CD0000	E 358	CALL OUTPUT ;'AA'
0214	011027	359	LXI B,10000 ;WAIT .5 SECOND
0217	CD0000	E 360	CALL WAIT
021A	C32E00	C 361	JMP PROG3Y
		362	
		363	
		364	;#####
		365	
		366	END

PUBLIC SYMBOLS
 PRG11B C 01F2 PROGR C 0000

EXTERNAL SYMBOLS

ASCHEX E 0000	ASCHX1 E 0000	DPROGM E 0000	ERROR E 0000
EXIT E 0000	GETPOT E 0000	HEXASC E 0000	HXASC1 E 0000
OPINFO E 0000	OUTPUT E 0000	PRADD E 0000	START1 E 0000
STATE E 0000	TRANSO E 0000	WAIT E 0000	XMIT E 0000

USER SYMBOLS

ASCHEX E 0000	ASCHX1 E 0000	CLOSE C 0105	DPROGM E 0000
END4 C 009D	ERROR E 0000	EXIT E 0000	EXTEND C 00FE
GETPOT E 0000	HEXASC E 0000	HXASC1 E 0000	LEFT C 00DF
LPRG1 A 0009	LPRG2 A 0012	LPRG3 A 0009	LPRG4 A 0006
LPRG5 A 000F	LPRG6 A 0008	LPRG7 A 000F	LPRGB A 0008
OPEN C 0106	OPINFO E 0000	OPRG1 D 0000	OPRG2 D 0009
OPRG3 D 0012	OPRG4 D 0024	OPRG5 D 002A	OPRG6 D 0039
OPRG7 D 0041	OPRG8 D 0050	OUTPUT E 0000	PRADD E 0000
PRG11A C 01EB	PRG11B C 01F2	PROG10 C 01CB	PROG11 C 01DC
PROG2 C 000E	PROG3 C 001D	PROG3Y C 002E	PROG4 C 003C
PROG4E C 0080	PROG4H C 0060	PROG4N C 00A7	PROG4S C 0070
PROG4W C 0090	PROG5 C 00BD	PROG6 C 0126	PROG6A C 014E
PROG7 C 013C	PROGB C 0185	PROG9 C 0197	PROGR C 0000
START1 E 0000	STATE E 0000	TRANSO E 0000	UP C 00E0
WAIT E 0000	XMIT E 0000	XSL C 017B	XSU C 0176
XX C 017D			

ASSEMBLY COMPLETE, NO ERRORS

ISIS-II ASSEMBLER SYMBOL CROSS-REFERENCE, V2.1

ASCHEX	17	77	236	287	325				
ASCHX1	17	68	224	276	313				
CLOSE	178	202*							
DPROGM	16	336							
END4	121	130	139	148*					
ERROR	15	112	179						
EXIT	15	62	71	93	151	194	231	243	282
	308	320							
EXTEND	172	196*							
GETPOT	16	247							
HEXASC	17	351							
HXASC1	17	347							
LEFT	174	181*							
LPRG1	33*	59	183	295	355				
LPRG2	34*	90							
LPRG3	35*	305							
LPRG4	36*	189							
LPRG5	37*	118							
LPRG6	38*	125	145						
LPRG7	39*	136							
LPRG8	40*	136							
OPEN	176	203*							
OPINFO	15	67	76	103	167	185	210	211	212
	213	214	215	223	235	275	286	297	312
	324	348	352	357					
OFRG1	24*	58	182	294	354				
OFRG2	25*	89							
OFRG3	26*	304							
OFRG4	27*	188							
OFRG5	28*	117							
OFRG6	29*	124	144						
OFRG7	30*	155							
OFRG8	31*	135							
OUTPUT	13	60	91	119	126	137	146	157	184
	187	190	296	299	306	356	359		
PRADD	13	69	78	148	160	170	225	237	250
	277	288	314	326	341	346	350		
PRG11A	216	271	336*						
PRG11B	11	346*							
PROG19	307	312*							
PROG11	319	324*							
PROG2	61	67*							
PROG3	70	76*							
PROG3Y	89*	362							
PROG4	92	99*							
PROG4E	109	132*							
PROG4H	105	116*							
PROG4N	100	155*							
PROG4S	107	123*							
PROG4W	111	141*							
PROG5	150	167*							
PROG6	193	221*							
PROG6A	222	247*							
PROG7	230	235*							
PROG8	242	275*							
PROG9	281	286*							
PROGR	11	58*							

ISIS-II ASSEMBLER SYMBOL CROSS REFERENCE, V2.1

PAGE 2

PROGN	1				
START1	16	163	264		
STATE	15				
TRANSO	14	102			
UP	169	182*	199		
WAIT	13	84	159	303	361
XMIT	16	116	123	132	141
XSL	255	257	263	267*	
XSU	253	259	261	265*	
XX	266	268*			

CROSS REFERENCE COMPLETE

ISIS-II 8080/8085 MACRO ASSEMBLER, V4.0

RDPOTH PAGE 1

LOC	OBJ	LINE	SOURCE STATEMENT	
		1	NAME	RDPOTH
		2		
		3	PROGRAMMER:	C. MORRIN
		4	VERSION	1.0W
		5	DATE OF LAST CHANGE:	OCTOBER 25, 1977
		6		
		7	*****	
		8		
		9	CSEG	
		10		
		11	PUBLIC	RDPOT
		12	EXTRN	START1,ERROR,EXIT,POTFLG
		13	EXTRN	DISPOT,OUTPUT
		14		
		15	*****	
		16		
		17	DSEG	
		18		
0000	20412C53	19	DT1:	DB 'A,S,E OR W?'
0004	2C45204F			
0008	5220573F			
000C	20412C55	20	DT2:	DB 'A,U OR L?'
0010	204FS220			
0014	4C3F			
		21		
000C		22	LT1	EQU 12
000A		23	LT2	EQU 10
		24		
		25	*****	
		26		
		27	CSEG	
		28		
		29	;HAND CONTROLLER INTERFACE:	
		30		
		31	READ POTENTIOMETER MODE, WHICH ONE?	
		32	RALL, SHOULDER GROUP, ELBOW GROUP,	
		33	; OR WRIST GROUP?	
0000	210000	D	34	RDPOT: LXI H,DT1
0003	0E0C		35	MVI C,LT1
0005	CD0000	E	36	CALL OUTPUT // SELECT: A/S/E/W'
0008	210E00	C	37	LXI H,INPT40
0008	C30000	E	38	JMP EXIT
		39		
		40	+++++	
		41	;READ POTENTIOMETER MODE, GROUP?	
		42	INPT40: CPI 'A'	
000E	FE41		43	JZ RALL
0010	CA2500	C	44	CPI 'S'
0013	FE53		45	JZ RSHLD.R
0015	CA4A00	C	46	CPI 'E'
0018	FE45		47	JZ RELBOW
001A	CA5800	C	48	CPI 'W'
001D	FE57		49	JZ RWRIST
001F	CA6600	C	50	JMP ERROR
0022	C30000	E		

LOC	OBJ	LINE	SOURCE STATEMENT
		51	
		52	; "ALL" SELECTED, READ ALL POTS:
0025	212500	C	53 RALL: LXI H,RALL
0028	220000	E	54 SHLD POTFLG
002B	3E00		55 MVI A,0
002D	CD0000	E	56 CALL DISPOT ;SU = 0
0030	3E01		57 MVI A,1
0032	CD0000	E	58 CALL DISPOT ;SL = 1
0035	3E02		59 MVI A,2
0037	CD0000	E	60 CALL DISPOT ;EU = 2
003A	3E04		61 MVI A,4
003C	CD0000	E	62 CALL DISPOT ;HU = 4
003F	3E05		63 MVI A,5
0041	CD0000	E	64 CALL DISPOT ;WL = 5
		65	
		66	; THIS IS THE "END OF READ POT" RETURN.
0044	217400	C	67 END40: LXI H,INPT41
0047	C30000	E	68 JMP EXIT
		69	
		70	; "SHOULDER" SELECTED, WHICH POT?
004A	210C00	D	71 RSHLDR: LXI H,0T2
004D	0E0A		72 MVI C,LT2
004F	CD0000	E	73 CALL OUTPUT ;' SELECT: A/U/L'
0052	218500	C	74 LXI H,INPT42
0055	C30000	E	75 JMP EXIT
		76	
		77	; "ELBOW" SELECTED, READ ELBOW POT:
0058	215800	C	78 RELBOW: LXI H,RELBOW
005B	220000	E	79 SHLD POTFLG
005E	3E02		80 MVI A,2
0060	CD0000	E	81 CALL DISPOT ;EU = 2
0063	C34400	C	82 JMP END40
		83	
		84	; "WRIST" SELECTED, WHICH POT?
0066	210C00	D	85 RWRIST: LXI H,0T2
0069	0E0A		86 MVI C,LT2
006B	CD0000	E	87 CALL OUTPUT ;' SELECT A/U/L'
006E	21C600	C	88 LXI H,INPT43
0071	C30000	E	89 JMP EXIT
		90	
		91	;+++++;+++++;+++++;+++++;+++++;+++++;+++++;+++++;
		92	;READ POTENTIOMETER MODE, UPDATE READING
		93	;OR GO BACK TO START? (U OR S?)
0074	FESS		94 INPT41: CPI 'U'
0076	CA8100	C	95 JZ UPDATE
0079	FE53		96 CPI 'S'
007B	CA0000	E	97 JZ START1
007E	C30000	E	98 JMP ERROR
		99	
		100	;READ POT AGAIN, POTFLG IS ADDRESS OF
		101	;APPROPRIATE ROUTINE.
0081	2A0000	E	102 UPDATE: LHLD POTFLG
0084	E9		103 PCHL
		104	
		105	;+++++;+++++;+++++;+++++;+++++;+++++;+++++;+++++;

LOC	OBJ	LINE	SOURCE STATEMENT			
		106	;READ SHOULDER POTENTIOMETER, WHICH ONE?			
0085	FE41	107	INPT42:	CPI	'A'	
0087	CA9700	C	108	JZ	RSA	
008A	FE55		109	CPI	'U'	
008C	CAA000	C	110	JZ	RSU	
008F	FE4C		111	CPI	'L'	
0091	CAB000	C	112	JZ	RSL	
0094	C30000	E	113	JMP	ERROR	
		114				
		115	;READ ALL SHOULDER POTS			
0097	219700	C	116	RSA:	LXI H,RSA	
009A	220000	E	117	SHLD	POTFLG	
009D	3E00		118	MVI	A,0	
009F	CD0000	E	119	CALL	DISPOT ;SU = 0	
00A2	3E01		120	MVI	A,1	
00A4	CD0000	E	121	CALL	DISPOT ;SL = 1	
00A7	C34400	C	122	JMP	END40	
		123				
		124	;READ SHOULDER UP POT			
00AA	21AA00	C	125	RSU:	LXI H,RSU	
00AD	220000	E	126	SHLD	POTFLG	
00B0	3E00		127	MVI	A,0	
00B2	CD0000	E	128	CALL	DISPOT ;SU = 0	
00B5	C34400	C	129	JMP	END40	
		130				
		131	;READ SHOULDER LEFT/RIGHT POT			
00B8	21BB00	C	132	RSL:	LXI H,RSL	
00BB	220000	E	133	SHLD	POTFLG	
00BE	3E01		134	MVI	A,1	
00C0	CD0000	E	135	CALL	DISPOT ;SL = 1	
00C3	C34400	C	136	JMP	END40	
		137				
		138				
		139	+++++;READ WRIST POTENTIOMETER, WHICH ONE?			
00C6	FE41		140	;READ WRIST POTENTIOMETER, WHICH ONE?		
00CB	CAB000	C	141	INPT43:	CPI 'A'	
00CB	FE55		142	JZ	RWA	
00CD	CAE000	C	143	CPI	'U'	
00D0	FE4C		144	JZ	RWU	
00D2	CAF900	C	145	CPI	'L'	
00D5	C30000	E	146	JZ	RWL	
		147	JMP	ERROR		
		148				
		149	;READ ALL WRIST POTS:			
00DB	21DB00	C	150	RWA:	LXI H,RWA	
00DB	220000	E	151	SHLD	POTFLG	
00DE	3E04		152	MVI	A,4	
00E0	CD0000	E	153	CALL	DISPOT ;WU = 4	
00E3	3E05		154	MVI	A,5	
00E5	CD0000	E	155	CALL	DISPOT ;WL = 5	
00EB	C34400	C	156	JMP	END40	
		157				
		158	;READ WRIST UP/DOWN POT:			
00EB	21EB00	C	159	RWU:	LXI H,RWU	
00EE	220000	E	160	SHLD	POTFLG	

LOC	OBJ	LINE	SOURCE STATEMENT		
00F1	3E04	161	MVI	A,4	
00F3	CD0000	E 162	CALL	DISPOT	;HU = 4
00F6	C34400	C 163	JMP	END40	
		164			
		165	;READ WRIST LEFT/RIGHT POT:		
00F9	21F900	C 166	RWL:	LXI	H,RNL
00FC	220000	E 167	SHLD	POTFLG	
00FF	3E05	168	MVI	A,5	
0101	CD0000	E 169	CALL	DISPOT	;WL = 5
0104	C34400	C 170	JMP	END40	
		171			
		172	END		

PUBLIC SYMBOLS
RDPOT C 0000

EXTERNAL SYMBOLS

DISPOT E 0000	ERROR E 0000	EXIT E 0000	OUTPUT E 0000
POTFLG E 0000	START1 E 0000		

USER SYMBOLS

DISPOT E 0000	END40 C 0044	ERROR E 0000	EXIT E 0000
INPT40 C 000E	INPT41 C 0074	INPT42 C 0085	INPT43 C 00C6
LT1 A 000C	LT2 A 000A	DT1 D 0000	DT2 D 000C
OUTPUT E 0000	POTFLG E 0000	RALL C 0025	RDPOT C 0000
RELBOW C 0058	RSA C 0097	RSHLDR C 004A	RSL C 00B8
RSU C 00AA	RWA C 00D8	RWL C 00F9	RWRIST C 0066
RWU C 00EB	START1 E 0000	UPDATE C 0081	

ASSEMBLY COMPLETE, NO ERRORS

ISIS-II ASSEMBLER SYMBOL CROSS REFERENCE, V2.1

PAGE 1

DISPOT	13	56	58	60	62	64	81	119	121
	128	135	153	155	162	169			
END40	67\$	82	122	129	136	156	163	170	
ERROR	12	50	98	113	147				
EXIT	12	38	68	75	89				
INPT40	37	42\$							
INPT41	67	94\$							
INPT42	74	107\$							
INPT43	88	141\$							
LT1	22\$	35							
LT2	23\$	72	86						
OT1	19\$	34							
OT2	20\$	71	85						
OUTPUT	13	36	73	87					
POTFLG	12	54	79	102	117	126	133	151	160
		167							
RALL	43	53\$	53						
RDPOT	11	34\$							
RDPOTW	1								
RELBOW	47	78\$	78						
RSA	108	116\$	116						
RSHLDR	45	71\$							
RSL	112	132\$	132						
RSU	110	125\$	125						
RWA	142	150\$	150						
RWL	146	166\$	166						
RWRIST	49	95\$							
RWU	144	159\$	159						
START1	12	97							
UPDATE	95	102\$							

CROSS REFERENCE COMPLETE

ASM80 :F1:RELAYN.ASY XREF PAGewidth(72) PRINT(:LP:)

ISIS-II 8080/8085 MACRO ASSEMBLER, V4.0

RELAYW PAGE 1

LOC	OBJ	LINE	SOURCE STATEMENT
		1	NAME RELAYW
		2	
		3	;PROGRAMMER: C.MORRIN
		4	;VERSION 1.0W
		5	;DATE OF LAST CHANGE: NOVEMBER 3, 1977
		6	
		7	*****
		8	
		9	;THESE ROUTINES START AND STOP THE RELAYS.
		10	;THE RSTART ENTRY POINT STARTS THE RELAY
		11	;INDICATED BY PRADD AND DIRFLG.
		12	;THE FUNCTION TO BE OPERATED IS ENCODED IN BITS
		13	;0,1,2 OF THE BYTE WHICH PRADD POINTS TO.)
		14	;DIRFLG INDICATES WHICH OF THE TWO RELAYS USED
		15	;BY THAT FUNCTION IS TO BE TURNED ON.)
		16	;
		17	;RSTOP STOPS THE RELAY.
		18	
		19	*****
		20	
		21	CSEG
		22	
		23	PUBLIC RSTART,RSTOP
		24	EXTRN RELAY1,PRADD,DIRFLG,ERROR,WAIT
		25	
		26	*****
		27	
0000 E5		28	RSTART: PUSH H
0001 C5		29	PUSH B
0002 2A0000	E	30	LHLD PRADD
0005 7E		31	MOV A,M ;GET FUNCTION
0006 E60F		32	ANI OFH
0008 CA3B00	C	33	JZ SHLDUP
000B FE01		34	CPI 1
000D CA4100	C	35	JZ SHDLDR
0010 FE02		36	CPI 2
0012 CA4700	C	37	JZ ELBOWU
0015 FE03		38	CPI 3
0017 CA4B00	C	39	JZ EXTND
001A FE04		40	CPI 4
001C CA5300	C	41	JZ WRISTU
001F FE05		42	CPI 5
0021 CA5C00	C	43	JZ WRISTL
0024 FE06		44	CPI 6
0026 CA5900	C	45	JZ WRISTR
0029 FE08		46	CPI 8
002B CA6B00	C	47	JZ HANDOP
002E FE09		48	CPI 9
0030 CA7100	C	49	JZ HANDCL
0033 FE0E		50	CPI 0EH
0035 CA7700	C	51	JZ XTEND
0038 C30000	E	52	JMP ERROR
		53	
003B 010100		54	SHLDUP: LXI B,1

LOC	OBJ	LINE	SOURCE STATEMENT	
003E	C37D00	C 55	JMP	RELYGO
0041	010102	C 56	SHLDLR: LXI	B,201H
0044	C37D00	C 57	JMP	RELYGO
0047	010200	C 58	EL80WU: LXI	B,2
004A	C37D00	C 59	JMP	RELYGO
004D	010300	C 60	EXTND: LXI	B,3
0050	C37D00	C 61	JMP	RELYGO
0053	010104	C 62	WRISTU: LXI	B,401H
0056	C35F00	C 63	JMP	R2
0059	C30000	E 64	WRISTR: JMP	ERROR
005C	010106	E 65	WRISTL: LXI	B,601H
005F	3A0000	E 66	R2: LDA	DIRFLG
0062	E6FF	E 67	ANI	OFFH ;SET ZERO FLAG
0064	C28600	C 68	JNZ	R1
0067	04	C 69	INR	B
0068	C38600	C 70	JMP	R1
006B	010202	C 71	HANDOP: LXI	B,202H
006E	C38600	C 72	JMP	R1
0071	010203	C 73	HANDCL: LXI	B,302H
0074	C38600	C 74	JMP	R1
0077	010300	C 75	XTEND: LXI	B,3
007A	C38600	C 76	JMP	R1
		C 77		
007D	3A0000	E 78	RELYGO: LDA	DIRFLG
0080	E6FF	E 79	ANI	OFFH ;SET ZERO FLAG
0082	CAB600	C 80	JZ	R1
		C 81	;CHANGE FROM UP (LEFT) TO DOWN (RIGHT):	
0085	04	C 82	INR	B
0086	78	C 83	R1: MOV	A,B
0087	320100	E 84	STA	RELAY1+1 ;SELECT FUNCTION
008A	C5	C 85	PUSH	B
008B	01D007	C 86	LXI	B,2000
008E	CD0000	E 87	CALL	WAIT ;WAIT .1 SEC
0091	C1	C 88	POP	B
0092	79	C 89	MOV	A,C
0093	320200	E 90	STA	RELAY1+2 ;START RELAY(S)
0096	C1	C 91	POP	B
0097	E1	C 92	POP	H
009B	C9	C 93	RET	
		C 94		
		C 95	*****	
		C 96		
0099	3E00	E 97	RSTOP: MVI	A,0
009B	320200	E 98	STA	RELAY1+2
009E	C9	E 99	RET	
		C 100		
		C 101	END	

PUBLIC SYMBOLS

RSTART C 0000 RSTOP C 0099

EXTERNAL SYMBOLS

DIRFLG E 0000 ERROR E 0000 PRADD E 0000 RELAY1 E 0000
WAIT E 0000

USER SYMBOLS

DIRFLG E 0000	ELBOWU C 0047	ERROR E 0000	EXTND C 0047
HANDCL C 0071	HANDOP C 0068	PRADD E 0000	R1 C 0086
R2 C 005F	RELAY1 E 0000	RELYGO C 007D	RSTART C 0000
RSTOP C 0099	SHDLR C 0041	SHLDUP C 003B	WAIT E 0000
WRISTL C 005C	WRISTR C 0059	WRISTU C 0053	XTEND C 0077

ASSEMBLY COMPLETE, NO ERRORS

ISIS-II ASSEMBLER SYMBOL CROSS REFERENCE, V2.1

PAGE 1

DIRFLG	24	66	78				
ELBOWU	37	58*					
ERROR	24	52	64				
EXTND	39	60*					
HANDCL	49	73*					
HANDOP	47	71*					
PRAOD	24	30					
R1	68	70	72	74	76	80	83*
R2	63	66*					
RELAYI	24	84	90	98			
RELAYW	1						
RELYGO	55	57	59	61	78*		
RSTART	23	28*					
RSTOP	23	97*					
SHLDLR	35	56*					
SHLDUP	33	54*					
WAIT	24	87					
WRISTL	43	65*					
NRISTR	45	64*					
WRISTU	41	62*					
XTEND	51	75*					

CROSS REFERENCE COMPLETE

ASMB0 :F1:TRANS.ASY XREF PAGewidth(72)

ISIS-II 8080/8085 MACRO ASSEMBLER, V4.0

TRANS PAGE 1

LOC	OBJ	LINE	SOURCE STATEMENT
		1	NAME TRANS
		2	
		3	/PROGRAMMER: C.MORRIN
		4	/VERSION 2.0
		5	/DATE OF LAST CHANGE: NOVEMBER 4, 1977
		6	
		7	;*****
		8	
		9	CSEG
		10	
		11	PUBLIC TRANS0
		12	EXTRN OUTPUT,PRADD,TAD,DPROGM
		13	EXTRN ASCHX1,EXIT,PRG11B
		14	EXTRN XMIT,PROMT,STOPFB
		15	
		16	;*****
		17	
		18	/OUTPUT MESSAGE TABLE:
		19	DSEG
		20	
0000	20235354	21	OTRAN1: DB ' *STEPS='
0004	4550533D	22	OTRAN2: DB ' TRANSFER FROM '
0008	20545241		
000C	4E534645		
0010	52204652		
0014	4F4BD20		
		23	
0008		24	LTRAN1 EQU 8
000F		25	LTRAN2 EQU 15
		26	
		27	;*****
		28	
		29	/PROGRAM TRANSFER ROUTINE (CALLED BY PROGRM)
		30	
		31	/PROGRAM TRANSFER MODE:
0017	3EF1	32	TRANS0: MVI A,OF1H
0019	320100	E	33 STA TAD+1
001C	210800	D	34 LXI H,OTRAN2
001F	0EOF		35 MVI C,LTRAN2
0021	C00000	E	36 CALL OUTPUT ;' TRANSFER FROM '
0024	212A00	D	37 LXI H,TRANS1
0027	C30000	E	38 JMP EXIT
		39	
		40	;*****
		41	/PROGRAM TRANSFER MODE, FIRST ADDRESS DIGIT
002A	FE2A	42	TRANS1: CPI #'
002C	CA3B00	D	43 JZ TRANS2
002F	C00000	E	44 CALL ASCHX1
0032	320000	E	45 STA TAD
0035	214400	D	46 LXI H,TRANS3
0038	C30000	E	47 JMP EXIT
		48	
		49	;*****
		50	/PROGRAM TRANSFER MODE, HARDWIRED MEMORY

LOC	OBJ	LINE	SOURCE STATEMENT
003B	C00000	E 51	TRANS2: CALL XMIT ;('*)
003E	218400	D 52	LXI H,TRANS5
0041	C30000	E 53	JMP EXIT
		54	
		55	;+++++PROGRAM TRANSFER MODE, 2ND ADDRESS DIGIT
0044	C00000	E 57	TRANS3: CALL ASCHEX
0047	210000	E 58	LXI H,TAD
004A	B6	59	ORA M
004B	77	60	MOV M,A
004C	210000	D 61	T3: LXI H,OTRAN1
004F	0E08	62	MVI C,LTRAN1
0051	C00000	E 63	CALL OUTPUT ;' *STEPS='
0054	215A00	D 64	LXI H,TRANS4
0057	C30000	E 65	JMP EXIT
		66	
		67	;+++++PROGRAM TRANSFER MODE, # OF STEPS
005A	C00000	E 69	TRANS4: CALL ASCHEX
005D	4F	70	MOV C,A
005E	2A0000	E 71	LHLD TAD
0061	EB	72	XCHG
0062	2A0000	E 73	LHLD PRADD
		74	;READY TO TRANSFER PROGRAM:
0065	0604	75	TRAN2: MVI B,4
0067	1A	76	TRAN1: LDAX D
0068	77	77	MOV M,A
0069	13	78	INX D
006A	23	79	INX H
006B	05	80	DCR B
006C	C26700	D 81	JNZ TRAN1
006F	C00000	E 82	CALL DPRGM
0072	3A0000	E 83	LDA STOPFG
0075	E6FF	84	ANI OFFH ;SET ZERO FLAG
0077	C20000	E 85	JNZ PRG11B
		86	;RETURN IF LAST STEP WAS A "STOP" FLAG
007A	220000	E 87	SHLD PRADD
007D	0D	88	DCR C
007E	C26500	D 89	JNZ TRAN2
0081	C30000	E 90	JMP PRG11B
		91	
		92	;+++++HARDWIRED MEMORY, 2ND ADDRESS DIGIT:
		+	
0084	C00000	E 93	HARDWIRED MEMORY, 2ND ADDRESS DIGIT:
0087	07	94	TRANS5: CALL ASCHEX
0088	5F	95	RLC
0089	1600	96	MOV E,A
008B	210000	E 97	MVI D,0
008E	19	98	LXI H,PROMT
		99	DAD D
		100	; (REG H) = POINTER TO HARDWIRED PROGRAM
008F	7E	101	MOV A,M
0090	320000	E 102	STA TAD
0093	23	103	INX H
0094	7E	104	MOV A,M

LOC	OBJ	LINE	SOURCE STATEMENT	
0095	320100	E 105	STA	TAD+1
0098	C34C00	D 106	JMP	T3
		107		
		108	END	

PUBLIC SYMBOLS
TRANSO D 0017

EXTERNAL SYMBOLS

ASCHEX E 0000	ASCHX1 E 0000	DPROGM E 0000	EXIT E 0000
OUTPUT E 0000	PRADD E 0000	PRG11B E 0000	PROMT E 0000
STOPFG E 0000	TAD E 0000	XMIT E 0000	

USER SYMBOLS

ASCHEX E 0000	ASCHX1 E 0000	DPROGM E 0000	EXIT E 0000
LTRAN1 A 0008	LTRAN2 A 000F	OTRAN1 D 0000	OTRAN2 D 0008
OUTPUT E 0000	PRADD E 0000	PRG11B E 0000	PROMT E 0000
STOPFG E 0000	T3 D 004C	TAD E 0000	TRAN1 D 0067
TRAN2 D 0065	TRANSO D 0017	TRAN51 D 002A	TRAN2 D 003B
TRAN3 D 0044	TRANS4 D 005A	TRAN85 D 0084	XMIT E 0000

ASSEMBLY COMPLETE, NO ERRORS

ISIS-II ASSEMBLER SYMBOL CROSS REFERENCE, V2.1

PAGE 1

ASCHEX	13	57	69	94			
ASCHX1	13	44					
DPROGM	12	82					
EXIT	13	38	47	53	65		
LTRAN1	24*	62					
LTRAN2	25*	35					
OTRAN1	21*	61					
OTRAN2	22*	34					
OUTPUT	12	36	63				
PRADD	12	73	87				
PRGJ1B	13	85	90				
PROMT	14	98					
STOPFG	14	83					
T3	61*	106					
TAD	12	33	45	58	71	102	105
TRAN1	76*	81					
TRAN2	75*	89					
TRANS	1						
TRANS0	11	32*					
TRANS1	37	42*					
TRANS2	43	51*					
TRANS3	46	57*					
TRANS4	64	69*					
TRANS5	52	94*					
XMIT	14	51					

CROSS REFERENCE COMPLETE

APPENDIX C: MODEL OF MANIPULATOR PROGRAMMER ACCURACY

REQUIRED ACCURACY

Level 1: Overall system accuracy is assumed to be a circle with diameter 0.5 inch.

Level 2: The system is divided into five functions, each of which has the same accuracy expressed in percent. The contribution of each function to the overall system accuracy is proportional to the distance between the function's sensor and the work area. The five functions are shoulder up/down (SU), shoulder left/right (SL), elbow up/down (EU), wrist up/down (WU), and wrist left/right (WL).

Assume that the distance between the sensor and the work area is fixed as follows:

Shoulder to work area = 6 feet
Elbow to work area = 4 feet
Wrist to work area = 2 feet

Case 2A

Assume that the errors are Gaussian and independent. Then the variance of the system error equals the sum of the variance of the subsystem errors.

$$\text{system error} = [(\text{SU error})^2 + (\text{SL error})^2 + (\text{EU error})^2 + (\text{WU error})^2 + (\text{WL error})^2]^{1/2}.$$

$$\begin{aligned}\text{SU error} &= (6 \text{ feet}) (2\pi) (270^\circ/360^\circ) \times \text{channel accuracy} \\ &= 9\pi \text{ feet} \times \text{channel accuracy} \\ &= 28.2 \text{ feet} \times \text{channel accuracy}\end{aligned}$$

Similarly,

$$\begin{aligned}\text{SL error} &= 28.2 \text{ feet} \times \text{channel accuracy} \\ \text{EU error} &= 16.7 \text{ feet} \times \text{channel accuracy} \\ \text{WU error} &= 8.4 \text{ feet} \times \text{channel accuracy} \\ \text{WL error} &= 8.4 \text{ feet} \times \text{channel accuracy}\end{aligned}$$

Hence system error = 0.5 inch = 600 inches \times channel accuracy. Therefore, channel accuracy = 1 part per 1200 = 800 ppm. Channel accuracy includes both data acquisition errors and hydraulic system consistency.

Case 2B

Assume that the errors are dependent. For example, the temperature-related errors will probably change as a group.

$$\text{system error} = [(SU \text{ error} + EU \text{ error} + WU \text{ error})^2 + (SL \text{ error} + WL \text{ error})^2]^{1/2}.$$

Since movements in the same direction are correlated (possibly canceling under some circumstances), orthogonal movements will follow the Pythagorean theorem.

$$\text{system error} = 0.5 \text{ inch} = 710 \text{ inches} \times \text{channel accuracy}.$$

Hence channel accuracy = 1 part per 1420 parts = 700 ppm. Note that the difference between independent and dependent errors is small. Channel accuracy must be between 700 and 800 ppm.

PRELIMINARY ACCURACY ANALYSIS PREDICTED ON THE BASIS OF THE DESIGN

The data acquisition system has four major components:

Sensor (potentiometer)
Multiplexer
Precision voltage reference
Analog-to-digital converter

Potentiometers

The potentiometers are used as voltage dividers. The output of the potentiometers is connected to a $100\text{-M}\Omega$ buffer amplifier; hence the current flowing through the potentiometers is constant.

The potentiometer should not be sensitive to temperature fluctuations, since any resistance change should be self-cancelling. But a potential problem with the potentiometers is a flat spot - where the resistance does not change. It is hoped that the solution to this problem is to use conductive plastic potentiometers and an extremely high resolution A/D converter; if we can measure the potentiometer voltage with much higher resolution than the nominal requirement, then it may be possible to divide the flat spots into distinguishable points.

Multiplexer Subsystem

The multiplexer includes two levels of MOS switches and two levels of instrumentation amplifier buffering. The switches have an impedance of $1\text{ k}\Omega$. The large changes in this impedance will be rendered insignificant by the $100\text{-M}\Omega$ input resistance of the instrumentation amplifiers. The leakage currents in the switches will not impact the accuracy.

The instrumentation amplifiers have an input and output offset, which will not impact accuracy as long as it is constant. The input offset temperature coefficient is $10 \mu\text{V}/^\circ\text{C}$, and the output offset temperature coefficient is $15 \mu\text{V}/^\circ\text{C}$. Since the signal is 20 V, the total offset temperature coefficient is $1.25 \text{ ppm}/^\circ\text{C}$. A specification for drift was not available. The noise figure is $20 \mu\text{V}$, or 1 ppm. The power supply provides 0.15% regulation, and the amplifier reduces this to 2.5 mV of noise per volt of ripple. Since the

power requirement is 30 V, the ripple noise is 100 μ V, or 5 ppm, for the 20-V signal.

Voltage Reference Subsystem

The voltage reference subsystem contains two voltage references (+10.000 and -10.000 V) and two current amplifiers. (The latter were required for the linkage manipulator pots and could be removed for the WSP pots.)

The voltage references have a temperature coefficient of 5 ppm and a drift of 50 ppm per year. Other specs include a noise figure of 5 ppm and a power-supply ripple of 4.5 ppm.

The current amplifier specs have not been calculated, since the components used are inexpensive and contain few specs. The current amplifiers are not required and will be removed if they are suspect.

Analog-to-Digital Converter Subsystem

The A/D converter has a temperature coefficient of 2.5 ppm/ $^{\circ}$ C and a quantization noise figure of 16 ppm.

Summary of Noise Sources

	Noise Error, ppm	Temp Error, ppm	Drift Error, ppm/year
Voltage ref			
Temp coef		200 (20 $^{\circ}$)	
Drift			100 (max)
Noise	10		
Power supply	9		
Multiplexer			
Temp coef		50 (20 $^{\circ}$)	
Power supply	10		
Noise	2		
A/D converter			
Temp coef		50 (20 $^{\circ}$)	
Quantization	16		
Total	21*	300**	100

* Square root of sum of squares, since sources are independent.

**simple sum, since temperature is dependent.

The predictable system errors are at least a factor of 2 better than the requirement. This analysis did not include noise from electromagnetic radiation, which was the predominant source of noise in the test. Self-noise appeared to be less than 500 ppm.

RESULTS FROM TESTING

As mentioned under test results, the measured accuracy was 800 ppm (circle of 0.5-inch diameter). This was attributed to an additional error source - electromagnetic interference from the low-pressure hydraulic pump. When this pump was off, the system noise was less than 200 ppm.

**ATE
LME**